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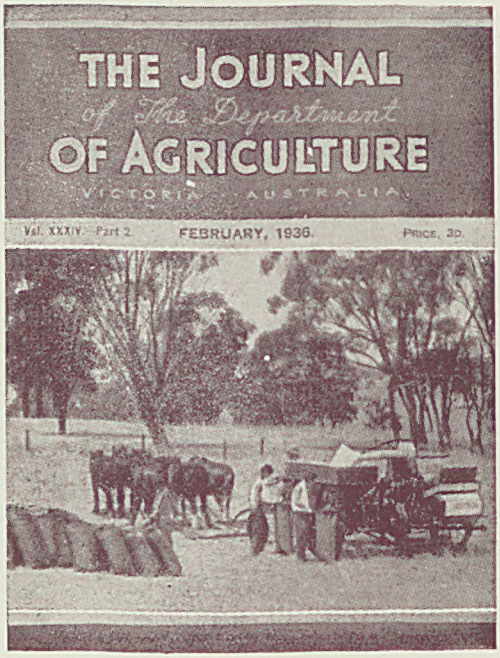

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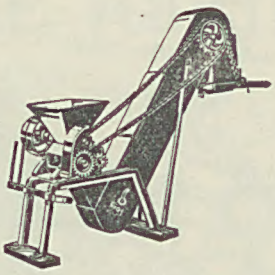

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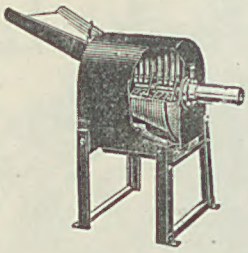

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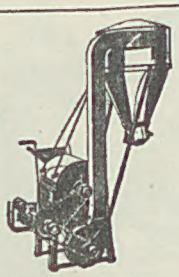

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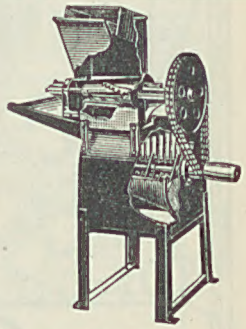

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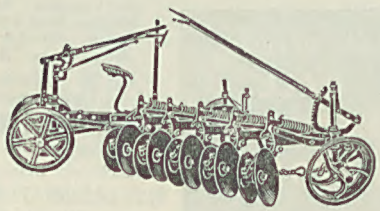

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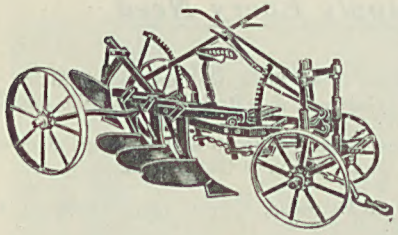

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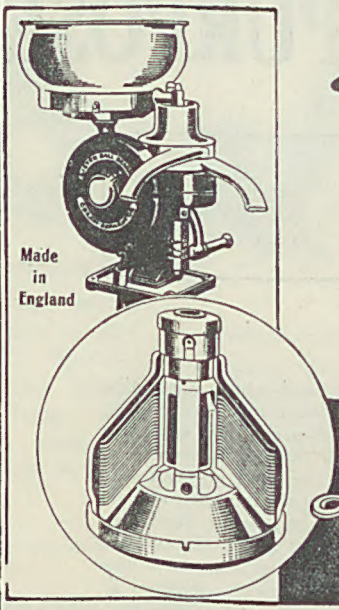

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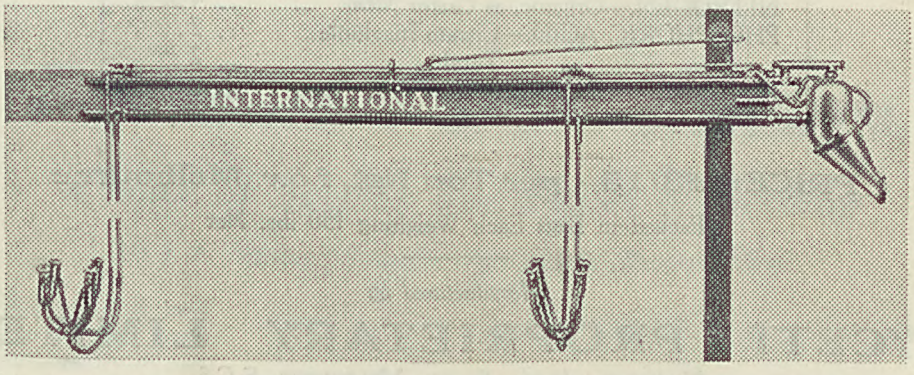

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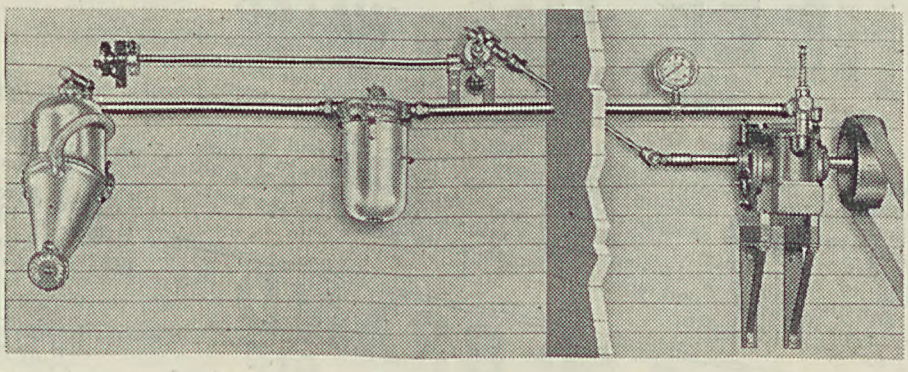

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The Journal of the DEPARTMENT of AGRICULTURE of VICTORIA

Permanent Pasture Mixtures

Choice of Species and Rates of Seeding

By J. E. Harrison, B.Agr.Sc., Agrostological Research Officer

WHEN a piece of land is to be laid down permanently to pasture, care is required in selecting species and strains, and in compounding a seeds mixture containing them in correct proportions. A wise choice of the most suitable strains will give persistency of the species, and if their seeds are mixed in correct proportions for sowing down, a dense well-balanced sward of grasses and clovers will develop early in the life of the pasture.

Twenty-inch rainfall country. Native grasses and annual plants make quick spring growth.

Species are selected to suit the rainfall and soils of a district, and to fulfil the special purposes of a pasture in relation to the needs of stock and the requirements of a farm. The total average annual rainfall is taken into account, its distribution from month to month, and its reliability from year to year. In the western districts of Victoria, the rain falls mainly during the winter, the summer being relatively dry, while in eastern districts about the same amount of rain falls from month to month throughout the year. Thus an average rainfall of 30 inches a year is somewhat different in effect in the Western District from what it is in Gippsland, and may necessitate the use of different species and strains.

The reliability of the rainfall decreases gradually from the coast towards the interior of Australia, and as temperature and therefore evaporation increase in the same direction, the rainfall is not only less dependable, but also less effective. The seasonal habits of a plant, such as time of germination, period of growth, and time of coming into ear, are very marked, and unless certain minimum requirements of soil moisture are maintained at these times, checks occur in the normal development of the plant.

In inland districts, therefore, where the rainfall varies very much from year to year, the seasonal requirements of plants are sometimes fulfilled, and sometimes not, and consequently a species may do well one season and poorly the next, This makes the establishment of permanent pasture more difficult and uncertain in these districts and may necessitate the use of different

species and strains from those which flourish in coastal areas.

Soils are often a deciding factor in the choice of species for permanent pasture. The effects of different kinds of soils appear to be the outcome of their reactions to the rains that fall more than to any other characteristic. The differences in the extent to which rains may be absorbed and retained, or lost by run-off or evaporation, create widely varying conditions of soil moisture in the various kinds of soils, which, therefore, become inhabited by different plant species. In any one area of similar rainfall, the soil types are often outlined by the different kinds of natural vegetation, field crops and pasture types, which follow the pattern of soil variation very closely.

It is not uncommon when a field has been sown down to a mixture of perennial rye grass and cocksfoot, to find that rye grass becomes dominant in one part and cocksfoot in another part of the field. The same selective action by two kinds of plants may take place when subterranean clover and white clover, one an annual, and the other a perennial, are sown together in the same field, and are found subsequently to occupy different portions. These and similar occurrences are familiar ones, and they illustrate that an understanding of the conditions under which each pasture species will grow well, will enable a farmer to place each species in its proper place and to economize in the purchase of seeds.

Fertility of the soil plays an important part in the growth of a species and sometimes in its persistence. Fertility is a fluctuating factor, which rises and falls with manurial treatment, the cultivation and methods of disposal of crops, and the kind of stock used in grazing. Even in early Roman times it was known that a leguminous crop raised the fertility of the soil and increased the yield of the following cereal crop ; and to-day in Victoria we are witnessing the improvement of much pasture land by cultivation of the legume, subterranean clover, and the subsequent satisfactory growth of perennial rye grass on soils which have hitherto barely supported it.

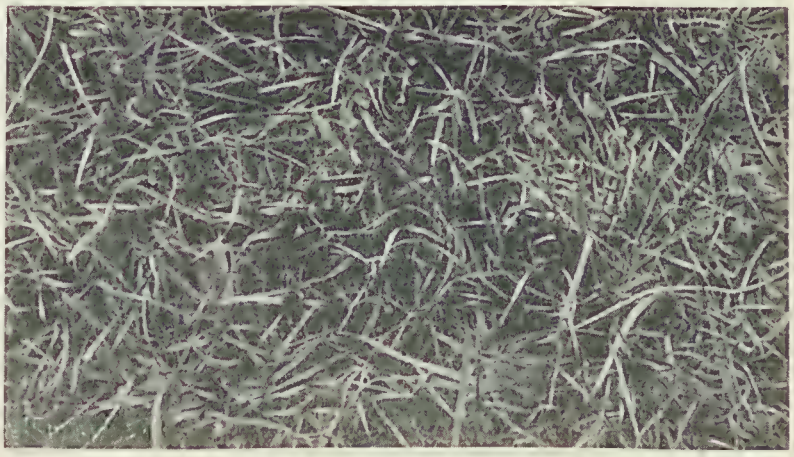
An increase of fertility usually is accompanied by an increase of organic matter in the soil, and though this does not change the soil type—it still remains a sand, loam or clay as the case may be—it generally results in an improvement in its water reactions, such as permeability or retentiveness, which may enable it to support a more productive species of pasture plant than formerly.

The natural restrictions as to what may and may not be sown on different soil types are often advantageous and may result in a greater variety of grazing and a better distribution of pasture growth throughout the year. If farm land does not lend itself naturally to the growth of different pastures, it is still usually desirable to grow more than one kind if possible, in order to supply the needs of farm stock for green feed more adequately and over a longer period.

The pasture species vary in their times of growth in both autumn and spring, and also in their response to summer rainfall ; and if a change can be secured from the one type of pasture which is likely to prevail on very uniform land, it will be found to have its advantages in certain years, and at certain seasons. In the past it has been usual to grow fodder crops to supply green feed during exceptional periods, but because of the relative simplicity of high pasture production, as well as the labour and expense of growing fodder crops, they have largely fallen into disuse. The limitations of certain pasture types in having marked periods of inactivity are realized, and unless this can be overcome or modified by the use of a variety of

A pasture grown under approximately 30-inch rainfall conditions in the Western District.

pasture types, it seems that the growing of fodder crops will come into vogue again, at least to some extent.



A perennial rye-grass stand showing suppression of weed and other growth.

Simple or Complex Mixtures.

During the past decade there has been a change of view by grassland workers in various countries as to the number of species which should be included in pasture mixtures. It was usual to include several species, and in old books on the subject, recommendations may be found which include as many as twelve or fourteen species. To-day it is not uncommon to see only two, a grass and a clover, recommended for soils of a limited capacity, though for highly fertile soils in districts of good rainfall more species usually are included in mixtures.

The circumstances which have led to the use of simpler mixtures have arisen mainly from recent knowledge of the importance of strain in pasture plants, of the competitive effect of one species upon another, and of the restricted adaptation of each species to certain soil and climatic conditions. It is possible, now, where it was very uncertain not many years ago, to select a strain of grass or clover which can be depended upon to persist. The former obligation to make provision for the possible or probable failure of either, by including other species, therefore does not exist to-day.

It has become apparent, however, that these persistent strains may be highly competitive, dwarfing the development of other species, and even eliminating them from the pasture. It is necessary to name the persistent strains of perennial rye grass as the chief offenders, and to emphasize at once that the proportions in which these strains are present very often determine the fate of other grasses, especially on soils that are primarily suitable to perennial rye grass.

It is recognized that if two or more grass species are present in a pasture, each species might be encouraged or retarded by appropriate grazing or resting at specific periods, but the extent of this type of control would appear to be limited by the rigidity of certain farm practices, by deficiencies in soil moisture, and by stock possibly selecting and grazing a different species from the one it is intended to check. The restricted adaptation of the various pasture species to certain soils and to certain rainfall districts has been indicated in Victoria during recent grassland investigations and has led to a simplification of mixtures. In a few cases also the unproductive nature of certain species like crested dogstail and sweet-scented vernal has led to their exclusion, in some cases, from seed merchants' catalogues.

Seed Proportions.

Another alteration of view taking place is in respect of the relative amounts of grass and clover seeds desirable in a mixture. It has been common practice in the past to sow large amounts of grass seed and small amounts of clover seed. Only a few years ago it was usual in the Western District to sow down 40 lb. perennial rye grass seed with 2 or 3 lb. clover seed per acre. Perhaps the mixture was compounded with an eye to its cost, as the local rye grass seed was relatively cheap, and clover seeds, especially subterranean clover, were a high price. But there has been a hardening of prices for rye grass seed of reliable strain, while the price of subterranean clover seed has eased considerably, so that any influence which prices might have would probably operate in the opposite direction at the present time.

A better reason for altering the ratio of grass seed to clover seed is the fact that a new pasture first becomes highly productive through the development of clovers under regular dressings of superphosphate. It is naturally desirable to reach this highly productive stage as quickly as possible, and for this reason a tendency has arisen to reduce the quantity of grass seeds sown and increase the quantity of clover seeds. There is a reason for both alterations, as a reduction in the amount of grass seed lowers the competitive effect of the grass upon the clover, and an increase in the amount of clover seed accelerates the development of the clover stage.

Lucerne trials in the Burnley Plant Research field. Lucerne is a good summer fodder crop in dry districts.

Another reason for sowing less grass seed is that the number of grass plants which ultimately persists in a pasture represents, as a rule, a small proportion only of the number of seeds which may be sown. For example the number of plants of perennial rye grass which ultimately persists in a field may be no greater than the number of seeds in 1 or 2 lb.

Quantity of Grass Seed.

There are several reasons, however, which make it necessary to sow a greater number of grass seeds than the number of grass plants which may ultimately persist in a pasture.

The capacity of grass seeds to germinate and establish seedlings under field conditions varies very much from sample to sample, and from species to species. In the case of rye grass, about 80 per cent. of seeds usually germinate, and of these, about 60 per cent. may be expected to give rise to seedlings. This means that even when a clean sample of seed is sown, only about half of it is effective and if impurities are present the result is lower still. This is one good reason for sowing more seed than is apparently necessary, but a more important one, at least in the case of perennial rye grass, is the control and suppression of weeds which are obtained if a relatively heavy seeding is made.

A further consideration affecting the amount of perennial rye grass seed which should be sown, both when it is the only grass sown and when it is included with other grasses, is the rapid growth and increased grazing which this species gives in the year of sowing down. Other perennial grasses and practically all the clovers make little growth in the first year, and very little grazing is obtained from them unless perennial rye grass is sown with them.

It is suggested, however, that perennial rye grass could be replaced, in part, by the short-lived rye grasses, such as Italian rye grass, New Zealand South Island rye grass, or Wimmera rye grass, which cost less to buy, are as effective in suppressing weeds, and give the same amount of grazing, or even more, in the year of establishment. The advantages of perennial rye grass, when heavily seeded in the first year, are offset by the continuance of its severe competitive effect upon clovers and other grasses in the second, and even in the third year of establishment. The use of a short-lived rye grass, with a light seeding of perennial rye grass, would retain the advantages of the first year while permitting the development of clovers in the second year, and so the more rapid development of a highly productive pasture might be expected.

The use of Italian rye grass at seeding time has been forgotten or overlooked during the past few years, but it would seem that it could again be accorded a place with advantage in the details of pasture establishment in certain districts. There was some fear that if Italian rye grass or other short-lived forms were sown with perennial rye grass, they might lead to a corruption of the perennial type by cross fertilization, but no evidence has been discovered to support this view. It appears safe to sow them together unless it is intended to harvest the field subsequently for seed, when no doubt the occurrence of Italian rye grass would contaminate the sample.

It is during the past decade only that grasslands have become the subject of scientific research and there is still much to learn about them. Many of the details which have been discussed, obviously need further investigation; the inter-actions of species which may compose a pasture have still to be fully studied; and new species and strains are wanted to supplement the rather limited number which can be successfully sown in Victoria to-day. An exact knowledge is wanted also of the different periods of growth of all our pasture plants, if a range of pasture types is to be formulated, which will give prolonged green grazing to the various classes of stock which graze our fields. Nevertheless, there is much sound knowledge available from the experimental work which has already been done, the experience of farmers in all phases of pasture establishment and management is increasing, and we are in a sounder position to lay down and maintain highly productive pastures than ever before.

(An article on "Species Recommended" will be published in a subsequent issue.)

Some Aspects of Plant Breeding—

Potato Improvement

By Alan R. Raw, M.Agr.Sc., Cereal Geneticist.

AS a result of thirty-five years of activity on the part of the plant breeder, to-day, there is available for cultivation a wealth of superior new varieties of the majority of the major crop plants. This superiority over pre-existing varieties may be expressed in increased yielding capacity, resistance to disease, improvement in quality, adaptability to special environmental conditions, and so on.

It is proposed to review, in a series of short articles, the advances that have been made in the breeding and improvement of the various crop plants.

Prior to the beginning of the present century, the possibilities of improving agricultural plants by crossbreeding were not fully appreciated. During the preceding 150 years, sporadic attempts to produce improved varieties of plants by this method had been made. It was realized, more or less clearly, that by crossing two distinct varieties of plants it was possible to bring about a rearrangement of the characters of the parent plants—to "break the type" as it were. It was the breeders' hope that, of the new combinations occurring among the offspring of these hybridized plants, types superior to the parent forms would be obtained. When such desirable plants were found, the task of the breeder was to isolate them in a form which would breed true to type. This was achieved by selection. With only a limited knowledge of the phenomena of heredity, however, this task was frequently beyond the powers of the plant breeder, and consequently, in many cases resulted in failure to secure a true breeding form—a "fixed" type. These failures left the impression that the hybrid plants always "threw back to the parents," that they were invariably unstable and consequently of little value to agriculture.

In the year 1900 came the rediscovery of the results of Mendel's epoch-making researches, conducted 40 years earlier, which laid the foundations of the science of genetics and opened up unlimited fields to the plant breeder. Gregor Mendel, monk and scientist, established the fact that the inheritance of the individual characters of the organism was no "hit or miss" affair, but that it was subject to certain definite laws. Consequently, if one knew enough about the ancestry and constitution of the two parents, one could predict with a certain degree of accuracy not only what their offspring would look like, but also the relative frequency with which different combinations of the parental characters would appear among them. The rediscovery of this work led to feverish activity in the scientific world. The value of Mendel's findings in their relation to the improvement of crop plants was established beyond doubt, and intensive schemes for crop improvement by modern plant-breeding methods were launched in most of the major countries of the world.

The improvement of crop plants by selecting desirable types as parent stocks has been practised, perhaps unconsciously, since the earliest times, but no marked progress was apparent in this direction until the early years of the nineteenth century, when the value of the individual plant as the unit of selection began to be appreciated. The major portion of the plant improvement work prior to the opening of the present century was based upon the selection of desirable types from existing populations. Many superior varieties were obtained by this method. The post-1900 work has been largely directed along the line of selection within artifically induced hybrid populations. In addition, selection within established populations has been further exploited as a means to the isolation of improved strains.

The cultivated potato, *Solanum tuberosum*, was introduced into Europe towards the end of the sixteenth century. The species, including all the cultivated forms of the Old World and North America, originated in Chili. There is evidence to suggest that the potato was cultivated in Chili and Peru thousands of years before the discovery of America. The recent South American expeditions of the Institute of Applied Botany and Plant Breeding, U.S.S.R., have revealed that a whole series of species of potatoes occur, many of them exhibiting characters of the utmost value to the plant breeder. These are discussed in detail later.

Following upon its introduction into Europe the potato has assumed a unique position in the domestic life of the community. It is probable that the initial importations were limited to two forms, and it has been established that the majority of the varieties cultivated at the present day are more or less direct descendants of these two original varieties. Because of this, the failure to isolate a blight immune variety from among the commonly cultivated European forms is not surprising.

Methods of Improvement.

The problem of the production of improved varieties of potatoes is an exceedingly complex one, since any attempts at improvement must of necessity deal with a wide range of characters relating to yield, disease resistance, colour, flavour, cooking and keeping qualities. adaptability to environmental conditions, and so on. Most, or perhaps all, of these characters must find embodiment in the new plant.

The problem is simplified to some extent, however, by the fact that several avenues of approach present themselves to the plant breeder. These may be briefly summarized as follow :—

A. *Introduction from Other Countries.*—The importation of established varieties from other countries may, and in many cases does, yield varieties of direct economic value. This method of obtaining improved varieties is especially likely to yield valuable results in those countries in which a definite potato improvement scheme has not been undertaken, or where such a scheme has been adopted but has not been in operation long enough to obtain fruition.

B. *Selection within Existing Populations.*—The problem of the production of improved varieties by selection may be attacked along two distinct lines—

(i) Intra-varietal selection using the individual plant as the unit of improvement.

(ii) Intra-varietal selection within the progeny arising from the seed of self-fertilized plants. This method is based upon the fact that the potato, being vegetatively re-produced, is heterozygous for most characters, i.e., unstable or unfixed, its progeny not all being true to type. It is also probable that considerable natural outcrossing takes place between varieties grown in proximity to each other.

These two methods in conjunction have been widely adopted in European countries and in America in the past, and have yielded outstanding results. The application of mass selection may, and does, result in spectacular improvements in regard to yield. This is due to the selection and propagation of disease-free plants. In general such methods are not attended by any permanent improvement.

The question of potato degeneration is closely bound up with the disease problem, particularly in its relation to the virus diseases and it has been demonstrated that, by the selection of healthy plants, the yield level of a variety may be maintained *ad infinitum*. The " regeneration " of varieties is also made possible by the adoption of this method of selection.

C. *Hybridization and Selection.*—This method of improvement offers the greatest promise of success. In reality it consists of selection within artificially-induced populations—the unit of selection being the individual plant.

The method has been widely adopted in the past and has led to the production of many outstanding varieties, particularly of forms possessing the character of disease resistance. Hybridization may be either inter-varietal or inter-specific, the latter aspect being a comparatively recent development, following upon the discovery of new species in South America. In recent years this has gained recognition as furnishing the most promising method of approach of the problem of potato improvement, more especially in regard to the production of varieties resistant to disease and/or frost.

Late Carman, a " sport " from Early Carman.

In addition to the production of new varieties by the methods outlined above, new forms

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WHAT A PERFECT COMBINATION

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VOLATILITY in petrol; FLUIDITY in motor oil—these are the two essentials for easy starting this winter. YOU GET BOTH by using Super Plume Ethyl and Winter Grade Mobiloil. This perfect combination for Winter motoring guarantees you Split-second Starting during the coldest days and nights. Avoid engine wear—save power—save petrol. During Winter—use this perfect combination . . .

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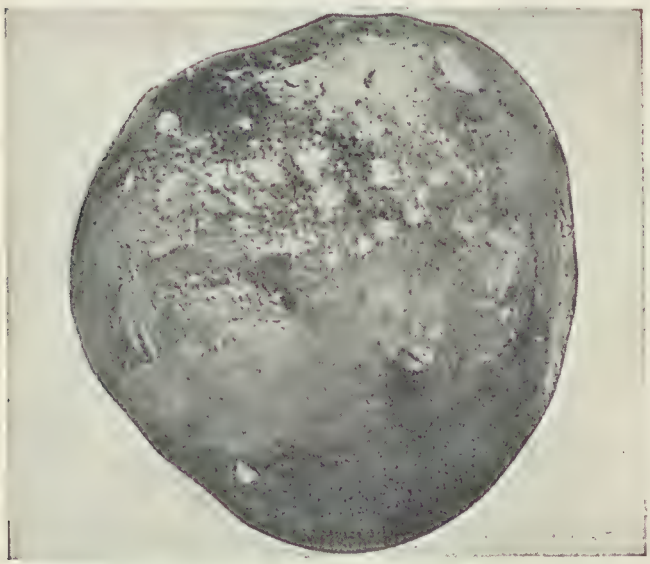


Potato showing white mould of Irish Blight fungus.

frequently arise by mutation or "sporting." These, however, assume little importance in the production of improved varieties.

The potato improvement problem has occupied the minds of the plant breeders of Europe and America for more than a century. The earlier attempts were based solely upon intra-varietal selection. The attention of the breeder was at first focussed entirely upon improvement as it relates to yielding capacity, quality and allied characters—and noteworthy advances were made in this direction.

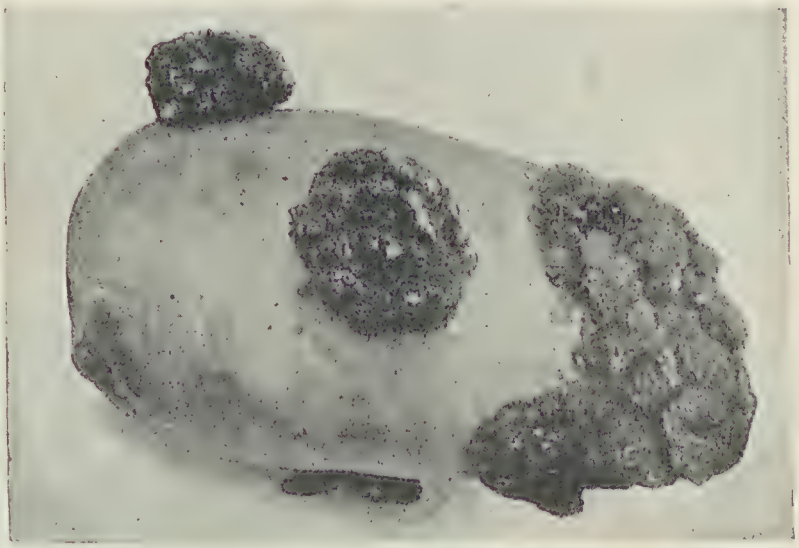
The Blight Problem.

In 1845, however, the attention of the potato breeder was diverted along an entirely new path. The Potato Blight (*Phytophthora infestans*) epidemic, spread over Europe with disastrous results, and in the following year practically wiped out the Irish potato crop. As a result the demand for blight resistant varieties became insistent, and this character and yield became conjointly the major objective of the breeding programme. The appearance of Wart (*Synchytrium endobioticum*), and several diseases of relatively lesser importance, added further to the problem of potato improvement.

The question of obtaining disease resistant varieties was still further complicated by the prevalence of the so-called virus diseases which are responsible for such pathological conditions as "mosaic," leaf curl, roll, &c. The presence of these diseases was recognized nearly two centuries ago, but their ravages were not so apparent as those of blight and wart disease and it was not until comparatively recently that they assumed a role of major importance to the plant breeder.

The introduction of the disease factor rapidly changed the potato improvement problem from a relatively simple one to one of an exceedingly complex nature. Despite this, the work of producing improved varieties continued, and great strides were made in combating the disease problem.

Outstanding amongst the earlier attempts to produce varieties resistant to blight were those which resulted in the production of Paterson's Victoria, which was introduced into cultivation about 1860. This variety, possessing desirable characters in regard to yield and quality, also exhibited a certain degree of resistance to the disease. It was isolated from among the progeny arising from the seed of a self-fertilized plant. This potato has exerted a dominant influence upon the production of new varieties during the past fifty years.



Wart disease, which is unknown in Victoria, also added to the problem of potato improvement.

A second potato which has left its mark is the variety Early Rose. This was produced in America by selection within the progeny of a self-fertilized variety imported from Chili. This selection work also yielded the variety, Beauty of Hebron.

During the past 80 years, several blight-resistant varieties have been developed from the cultivated forms of Europe, and North America. One of these, Champion, a high yielding potato of excellent quality and flavour, also exhibited a marked resistance to blight. It was observed, however, that the variety after being in cultivation for some time, gradually lost its power of resistance to the disease, a fact which was later correlated with the development of virus disease in the plant. When virus free stocks were selected, the character of blight resistance again manifested itself. A more recent production, Foster's Rust Proof, has been evolved in America from the progeny of a composite cross involving four parent varieties—Irish Cobbler, Green Mountain, Carman, and Beauty of Hebron. This new variety represents a distinct advance in the production of blight resistant types.

New Species.

Though many varieties exhibiting a high degree of resistance to the blight organism have been produced in the past, no truly immune forms have been obtained. This has led breeders to the conclusion that the character of immunity does not exist among the cultivated potatoes of Europe and North America.

During recent years, therefore, attention has been directed towards the discovery of new forms of potatoes in which the character of immunity was present. The first advance in this direction was in the discovery that the South American species, *Solanum demissum*, possessed the character in full development. Members of this species mated with the cultivated potato have given rise to the German "W races," which are truly immune to the disease. From a study of hybrids it was proved conclusively that while the mode of inheritance of the immunity factor was of a highly complex nature, the character itself was not linked with any of the other economically important characters of the plant.

The production of these "W races" represents a marked advance towards the solution of the breeding problem. The position has been still further advanced by the discovery of a whole new series of species of Solanum in South America. The bulk of this work of discovery and establishment has been carried out by the plant breeders of the Institute of Plant Breeding, Leningrad, U.S.S.R., who have conducted several expeditions in South America.

The species include forms exhibiting a vast wealth of new characters of definite value to the plant breeder, and their discovery brings the solution of many of his major problems much closer. The more important of these new species are those whose members exhibit the character of resistance to, or immunity from, blight. Outstanding among these are *Solanum demissum* (72), *S. semidemissum* (60), *S. Antipoviczii* (48), *S. Ajuscoense* (48), *S. andigenum* (48), *S. Verrucosum, S. polyandenium, and S. bulbocastatum.*

The species *S. andigenum* is of interest since it represents the cultivated potatoes of the Andes. In addition, members of this species hybridize very readily with those of *S. tuberosum* and other species. Several species, *S. acaule* (48), *S. curtilobum* (60), *S. Juzepczukii* (36), and *S. ajanhuiri* (24), are of importance since their members exhibit a marked degree of resistance to frost—which is a problem of great magnitude in many potato growing countries. The species *S. phureja* (24) and *S. chauca* (36) include among their members several forms of extreme earliness of maturity—while *S. medians* (24) and *S. vavilovii* (24) are represented by types which are highly drought resistant.

The bracketed numbers indicate the chromosome complement of the various species. (Chromosomes are the units responsible for the transmission of the hereditary characters. Each plant cell posesses a definite number which is constant for the species.) In this regard the common cultivated potato *S. tuberosum* is intermediate, the chromosome complement being 48. The species furnish an excellent example of a polyploid series in nature.

Many of these new species have already been incorporated in the Soviet potato improvement scheme, in order to exploit the desirable characters which they exhibit, and several new varieties of definite economic value have been developed in this way. The inclusion of some of the species in the breeding programme involves certain difficulties associated with differences in the chromosome complement of the individuals. These, however, may be largely overcome by the careful selection and arrangement of parent material, and by the adoption of systems of multiple hybridization involving perhaps three or four parent forms. The method employed is to cross two forms, and then to mate the first generation progeny of these with a third form. In this way it is frequently possible to obtain, indirectly, desirable combinations of species which are normally incompatible.

With the wealth of material available the possibilities of the ultimate solution of the blight problem appear to be very bright.

Other Diseases.

In regard to the problem of resistance to the virus diseases, however, the position is not so far advanced. The complex nature of the problem, which is not yet fully understood, presents very real difficulties to the plant breeder. A moderate degree of success has been met with in the production of resistant types, both in Europe and America, and at the present time there are available a score or so of varieties which exhibit some degree of resistance to one or other of these diseases. This, in conjunction with the discovery of resistant species (*S. Rybinii* (24)) in South America leads one to believe that the problem will eventually be solved. In the meantime, the most obvious method of attack is by the mass selection of virus-free plants for the building up of seed stocks.

Probably the greatest advances that have been made in the production of improved varieties of potatoes have been achieved in relation to the problem of resistance to wart, a disease which happily, does not concern us in Victoria. During the past 50 years, an extensive list of varieties immune from this disease has been evolved by the plant breeders of Europe and America. The production of these was accelerated by the fact that the immunity character is not linked with other economically important plant characters. Notable examples of the more recently produced wart immune varieties are furnished by several members of the famous Arran series produced by MacKelvie in Scotland. Several of these are also resistant to blight.

The Present Position.

As a result of more than 100 years of potato improvement work, there are available to-day extremely high yielding varieties which exhibit all or most of the desirable characters of the plant. During the past 70 or 80 years the problem of resistance to disease has largely dominated the breeders' outlook. Disease resistant forms of economic value have been evolved and are in cultivation. Many of the problems of disease resistance still await solution, but with the wealth of material available for breeding, there can be little doubt but that this aspect of the breeding programme will be brought to a successful termination.

Mosaic caused by Virus Disease.

The outstanding advance of recent years is undoubtedly the discovery of the new species of Solanum, since the introduction of these has opened up unlimited fields for the plant breeder and has furnished him with new weapons for the attack on the problems of disease, and frost resistance. Because of this the outlook of the potato breeder is exceedingly bright.

The Small Dairy Farm

By J. Robertson, Dairy Supervisor

WITHIN the last seven or eight years, the incomes from many holdings have been so reduced that farming on them has gradually become unprofitable, particularly those devoted mainly to wheat, fruit, sheep and poultry. A consequence is that, as in previous times of stress, people have turned to dairy-farming, and in the last few years the number of milking-cows in the State has increased by 300,000.

It may surprise many people to learn that in Victoria there are approximately 12,000 herds consisting of from 5 to 10 cows. Recent statistics show that half the dairy herds in the Geelong district belong to this group, and here and there throughout the State there are many herds of even less than 5 cows. Dairying on such a small scale cannot be a farmer's sole means of livelihood, and the person milking not more than 9 or 10 cows must be regarded as a "part-time" dairyman. It requires a herd of 14 or 15 to provide a full-time job for one man.

It seems likely that a great proportion of the small farms will be established permanently. They present problems somewhat different from those of the larger holding, for the small farmer, not definitely committed to any particular product, is rarely in a position to raise capital for work which can be regarded as little more than a "side-line."

As in other occupations, there is need for "tools of trade", and if the best returns are to be secured, the equipment must be efficient.

A Combined Wash-up Room and Brick Dairy.

Some sort of shedding and a dairy are essential for every farmer, and of these there are many types. The advice of the District Dairy Supervisor should be obtained when buildings are being planned, as his opinion of such structures will be sought when a licence is applied for.

Certain requirements in dairy buildings are prescribed by regulations made under the Milk and Dairy Supervision Act. No detached dairy, with separator room and cream storage, should be of less dimensions than 8 ft. x 8 ft. x 8 ft.

The size required in a dairy will depend on the number of cows to be milked and whether it is to be used for butter-making purposes. Cream storages should be 30 feet from the cow-shed with a sufficient clearance from the dwelling and other sheds. No engines of any sort should be placed in the separator and cream-storage rooms, as odors from them are liable to taint both milk and cream.

It goes without saying that advantage should be taken of any natural shade offering when a site is being selected.

Herd Test figures show that almost twenty per cent. of the cows tested produce more than 300-lb. of butter-fat per annum.

In small herds, where extra care and attention can be given, an average yield of this quantity should be obtained; indeed no farmer ought to be satisfied with less. In order to build up a satisfactory herd, stock should be obtained from owners who can sell calves from parents with proved production records. With a herd of ten

A New 3-bail Cow-shed. (Two posts only in the 13ft. x 18ft. concrete floor.)

Mr. G. Wilsher's cow-shed at Moriac (Note top of tank referred to on page 388.)

yielding an average of 300-lb. butter-fat, worth, say, one shilling per lb., the annual return would be £150, plus from £10 to £12 for skim milk. Of course when arriving at the return from any farm, the cost of feeding must be considered.

When building a cow-bail, some points essential to its efficiency are often overlooked. Sometimes the bail-opening is set with its centre less than six inches from the wall or the division post, which results in the real "dairy cow", that is one with a capacious middle, being made to hold her head in an indirect line with the rest of her body; and this condition is made worse when she is legroped. If the opening for the cow's neck is made at least 12 inches from the left division wall or post, the cow will be able to stand in comfort.

Bails are frequently too narrow to permit the milker to move about freely. When a herd does not exceed ten, usually a couple of bails will be enough; when the number is not more than five, a single-bail shed should suffice. Certainly a slightly larger shed has many advantages. One with three bails should be about 15 feet in length; it could be made with or without walk-through doors and with or without feed-box attachments.

Two 5 in. x 2 in. rails make an effective partition between the bails. They should be mortised or bolted to the rear post and to strong studs in the front wall. The lower rails should be about 15 inches clear of the floor and the top one 15 inches higher.

Division rails are purposely made strong so that they may be carried from the front wall to the back bail post without any supporting post between; they then entirely carry the front bail fittings. If the bail fittings across the front portion of the stalls are supported on division rails, no portion of the bail-timbering, except the rear post, need connect with the floor. This allows for a 15 inch clearance right through and greatly facilitates shed cleaning. The two cross-timbers should be 20 i ches and 5 feet respectively from the floor.

In writing so far, I have had in mind the "back-out" type of bail; but what has been said applies equally to the "walk-through" type, except that with the latter the front must be made fit for traffic, and a few slight structural alterations for exit purposes will also be necessary.

The wall foundations of the shed should be well raised above floor level and the wall plates bolted on them. Most modern sheds have concrete floors and any "handy man" can make a good job of them. Cement-grouted brick floors also give good service. The surface must not be too smooth, and the fall from the front of the shed to the rear ought not to be more than about 1 in 50.

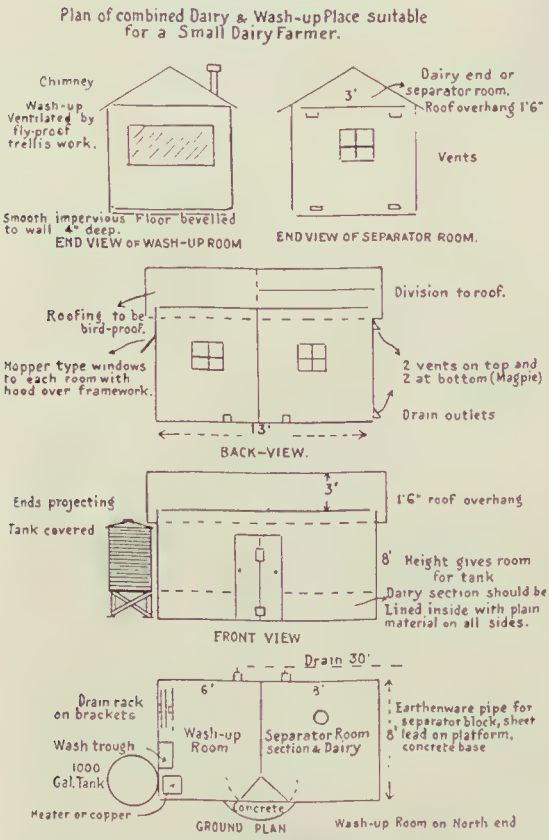
A drain is essential immediately at the rear of the cows, and it must be carried for a distance of at least 30 feet beyond the shed; a fall similar to that in the shed will suffice. Sometimes a common draining system for both shed and yards can be installed, but on no account should the cows have access to, or pass through the drainage, when entering or leaving the yard or shed.

Sufficient consideration is not always given to the site of the yard; this is particularly so in hill country. Every effort should be made to have the yard or yards on the lower side of the shed; the drainage must never pass the dairy end of the building. If the yard is not naturally high

Small Dairy and Wash-up Room built in accordance with plan on page 388.

enough it should be raised to ensure a free get-away of the drainage.

The type of feed-box used should be such as will prevent the cows tossing feed over the sides; fodder-strewn and dusty floors are both unsightly and insanitary. A sheet of plain iron nailed lengthwise on the lower wall portion improves the appearance and helps to keep the bails clean.


Plan of combined Dairy & Wash-up Place suitable for a Small Dairy Farmer.
Chimney
Wash-up Ventilated by fly-proof trellis work.
Smooth impervious Floor bevelled to wall 4" deep.
END VIEW OF WASH-UP ROOM
3'
Dairy end or separator room.
Roof overhang 1'6"
Vents
END VIEW OF SEPARATOR ROOM.
Roofing to be bird-proof.
Division to roof.
Hopper type windows to each room with hood over framework.
2 vents on top and 2 at bottom (Magpie)
Drain outlets
13'
BACK-VIEW.
Ends projecting
Tank covered
3'
1'6" roof overhang
8' Height gives room for tank
Dairy section should be Lined inside with plain material on all sides.
FRONT VIEW
Drain 30'
Drain rack on brackets
6'
3'
Earthenware pipe for separator block, sheet lead on platform, concrete base
Wash trough
Wash-up Room
Separator Room section & Dairy
1000 Gal. Tank
Heater or copper
Concrete
GROUND PLAN
Wash-up Room on North end

Green-hide leg-ropes have much to commend them; they are cheap and strong, and further, do not absorb urine and manure as freely as does fibre rope. They should be affixed low down on the rear post (but clear of the floor) to control a cow likely to kick.

Provision should be made for running water for washing the milker's hands; the same supply can be used for washing the cows' udders. A drum of ample size with tap attached will be found satisfactory. Dirty hands mean dirty milk, for milk can never be cleaner than the hands that draw it.

When buckets (seamless ones should always be used) are temporarily put aside during milking operations, as sometimes happens, they should not be set down on the floor of the shed, but either stood or hung up above the line of splashes from the animals. If hung up, they will not be so likely to be contaminated by particles of dirt. A bench should be provided for milk cans, and the cans should always be covered when flies are troublesome.

A bass broom, square-mouthed shovel and a wheelbarrow or manure-sledge are all part of a good dairyman's equipment. The judicious use of air-slaked lime will help in the cleaning of drains; it will also serve to deodorize the floors and sweeten the shed atmosphere, but should be used only on fairly dry floors.

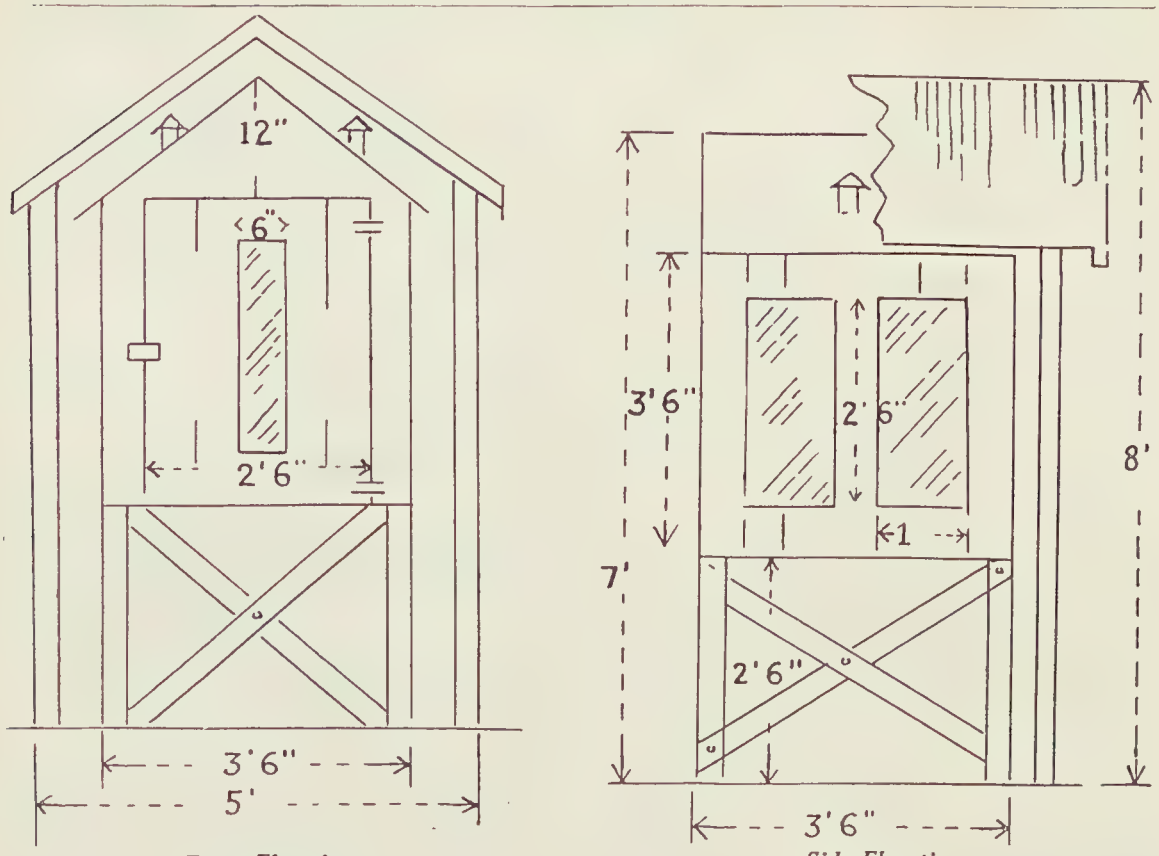
A clean shed and drains are effective as a means of securing good cream, only if cleanly conditions of milking and uncontaminated utensils are the invariable rule. The dairy-farmer must wage constant war against the "germ army". These organisms, which multiply very quickly under favorable conditions, are the real cause of the deterioration of cream and they can be kept in subjection only by cleanliness and coolness at every stage of milk and cream production.

Limewash is recommended for keeping a milking-shed sweet and sanitary. It also adds brightness to a building's appearance.

Every year a great deal of water runs to waste from the roofs of farm buildings, some of which could be stored at small cost.

At Moriac, Mr. Geo. Wilsher has had an underground tank of 6,300 gallon capacity constructed. It is 13 feet deep and 10 feet in diameter and its total cost was £4 10s. It was made in the following way:—A hole was bored in the ground in which a perpendicular pipe was placed. One end of a 5 foot hardwood board was fitted over the pipe so that it would inscribe a 10 foot circle. As the tank was deepened the board was used to keep the wall true. Outside the circle, a trench was dug, about 5 feet deep and almost the width of a spade and was filled with concrete to form the top of the tank wall. If at any time it is desired to increase the capacity of this tank, the wall may be carried up to the level of the spouting on the lowest roof.

When sinking such a tank, the excavation should be made to the required depth as soon as the concrete in the trench has set. Reinforcing material, such as wiremesh, cyclone or woven wire is then pegged on to the wall and the concrete applied direct to the wall, which should have been well wetted. From 3 to 4 inches of concrete should be placed on the bottom of the tank; this need not be reinforced. The job may be finished off with a "floater"; for this a half and half mixture of sand and cement may be used.



Front Elevation. *Side Elevation.*

Design for Cream Storage Room for a Small Dairy Farm.

Because of the abundance of water for cream-cooling and shed-cleansing, and the care of his produce generally, Mr. Wilsher has been able to secure a premium for his cream from a Geelong ice cream manufacturer. It was also of great assistance on two occasions in helping him to win the prize for sanitation in the State-wide Dairy Farm Competition.

Galvanized iron tanks are often more costly than underground ones, and with them depreciation is always an expensive item. Further, owing to their limited capacity, they run dry in summer and a failing water supply is sometimes made the reason or the excuse for leaving the separator unwashed at night—a practice which, because of its harmful effects on both machine and cream, cannot be too strongly condemned.

On a large dairy farm, a separate cream storage should be provided in a cleaner atmosphere than is usually attainable about the sheds and yards, but in the smaller farms a small separator room, dairy and wash-room will suffice. A plan of such a building is shown on page 388. The dairy section should be lined and ceiled with some light material like fibrolite. The overhanging roof will provide a considerable amount of shade for the four walls as well as a good water catchment.

The separator should be set up in clean surroundings, for air is drawn in to the machine as it works, and consequently it will be contaminated if the atmosphere is unclean. In order to secure cream of the best quality one must be always on

Side view of Small Storage Room built in accordance with above plan.

the alert to suppress all possible causes of dust, dirt, sourness and mustiness, as well as fumes and odors of every kind.

"Cool and clean" should be the dairy farmer's watchwords. The supply of cream from a small herd often does not warrant a daily delivery to the factory. Under such conditions, cooling the cream and maintaining it at a temperature of at least 60° F. is imperative. On page 389 is shown a plan of a cheap and efficient cream storage room. Of course the provision of some shade for a room of this sort is essential.

Cream coolers to suit all sizes of dairies can be had. In addition to cooling, aeration takes place as the cream passes in a thin layer over the surface of the cooler, and thus some of the "feedy" flavours escape and taints are minimised.

The cooler should be so adjusted that the cream will be evenly distributed over the whole cooling surface. If the quantity of water used be sufficient it should be possible to reduce the temperature of the cream to within 3 degrees of that of the water used, and it must then be kept cool until delivered at the factory.

Butter Production and Export

The following tables show :—

(*a*) Factory production of butter and cheese in Victoria for the period July, 1935, to February, 1936, and for the months of March, April, and May, 1936, compared with the corresponding periods of 1934 and 1935 ; and

(*b*) Quantities and percentages of various grades of bulk butter examined in Victoria from 1st July, 1935, to 30th June, 1936, in comparison with the corresponding period of 1934–35.

(*a*) Factory Production of Butter and Cheese in Victoria (Quantities in Tons).

Month.	Butter.		Cheese.	
	1935–36.	1934–35.	1935–36.	1934–35.
July to February (inclusive)	52,747	49,178	3,859	3,282
March	3,589*	4,401	264	307
April	2,852†	3,933	223*	320
May	2,386†	3,414	200†	314
Totals, eleven months ..	61,574	60,926	4,546	4,223

* Revised. † Subject to revision.

(*b*) Bulk Butter Examined for Export in Victoria (Quantities in Tons).

Period.	1935–36. How Graded—				Total.	Period.	1934–35. How Graded—				Total.
	Choice.	1st.	2nd.	Pastry.			Choice.	1st.	2nd.	Pastry.	
1st July to 30th May	22,304	11,652	2,832	430	37,218	1st July to 1st June ..	16,470	17,900	3,290	488	38,148
31st May to 30th June	41	19	29	8	97	2nd June to 30th June ..	509	213	48	4	775
Totals 1st July to 30th June ..	22,345	11,671	2,861	438	37,315	Totals 1st July to 30th June ..	16,979	18,113	3,338	492	38,923
Percentages ..	59·9	31·3	7·6	1·2	..	Percentages ..	43·6	46·5	8·6	1·3	..

Poultry Feeding Tests

Experiments at Werribee

By W. O. Pederick and A. G. Clark

DURING the twelve months from 1st April, 1935, to 31st March, 1936, ten different poultry feeding tests were conducted at the State Research Farm, Werribee. For the purpose, 250 Australorp pullets were selected and placed in five pens of 50 each, and 250 White Leghorn pullets were similarly divided. The results, as in previous tests, indicate that satisfactory results can be obtained with many kinds of feed given in varying quantities.

The table, on page 393, gives details of the various rations and the number of eggs laid in each pen. The cost of feed was arrived at by taking the wholesale prices as published in the press weekly, and eggs were valued on the wholesale prices for standard grade eggs. No deductions have been made for marketing charges, &c.

Hereunder are given details of the food supplied to each pen and the profit derived :—

Pen No. 1—*Australorps.*—The birds in this experiment were fed on the free choice system, i.e., all the different varieties of food were placed in separate hoppers, to which the birds had access all the time.

The proportion of grain eaten was very much higher than in pens 3 to 5, in which the birds were fed on the usual wet and dry mash systems. 3,418 lb. grain and 732 lb. meals were consumed. The order of preference of meals was: pollard, bran, meat meal, key meal; of grain it was: wheat, maize, barley, oats.

	£	*s.*	*d.*
Value of eggs laid ..	35	16	3
Total cost of food ..	12	9	10
Profit	23	6	5

Pen No. 2—*Australorps.*—The birds were fed on a dry mash mixture in the proportion of 3 lb. bran, 6 lb. pollard, 1 lb. meat meal, and 1 lb. key meal. This was available all the time. Free choice of grain was also available, similar to that fed Pen No. 1; the order of preference was: wheat, oats, maize, barley.

The consumption of food in Pen No. 2 was much less than in Pen No. 1, and although the production of eggs was slightly less the profit over cost of food was higher.

	£	*s.*	*d.*
Value of eggs laid ..	35	5	3
Total cost of food ..	9	12	9
Profit	25	12	6

Pen No. 3—*Australorps.*—The birds in this pen were fed on a dry mash similar to that given the birds in Pen No. 2, with the exception that no key meal was included. The grain consisted of a mixture in the proportion of 3 lb. wheat, 1 lb. oats, 1 lb. maize, and 1 lb. barley, fed in the litter during the afternoon.

The food consumption was 15 lb. per bird more than in Pen No. 2, but the net profit was $4\frac{3}{4}$d. per bird less.

	£	*s.*	*d.*
Total value of eggs ..	36	6	8
Total cost of food ..	11	14	6
Profit	24	12	2

Pen No. 4—*Australorps.*—These were fed on wet mash consisting of similar materials to those in the dry mash allowed to Pen No. 3. It was fed in the morning, and mixed grain, similar to that fed to Pen No. 3, was given in the afternoon.

The consumption of food was 7 lb. per bird less than in Pen No. 3, and the profit, over cost of food, was $8\frac{3}{4}$d. per bird more.

	£	*s.*	*d.*
Total value of eggs ..	37	4	3
Total cost of food ..	10	14	3
Profit	26	10	0

Pen No. 5—*Australorps.*—Fed on wet mash and mixed grain similar to that given in Pen No. 4, with the exception that 2 per cent. of dicalcic phosphate was added to the wet mash

as a mineral supplement. The quantity of food given was the same as that in Pen No. 4; the net return was 5¼d. per bird less.

No noticeable benefit resulted from the inclusion of the dicalcic phosphate, but this does not discountenance its value. All the birds in the test received an abundance of green food from land that had been heavily top-dressed with artificial manure; had this not been so, the addition of the dicalcic phosphate would almost certainly have proved its value as an aid to egg production.

	£	s.	d.
Total value of eggs ..	36	4	2
Total cost of food ..	10	16	5
Profit	25	7	9

Pen No. 6—*White Leghorns.*—The birds in this pen were fed on wet mash, the proportions being 3 lb. bran, 6 lb. pollard, 1 lb. meat meal, and 1 lb. key meal. Mixed grain was fed in the litter during the afternoon in the proportions of 3 lb. wheat, 1 lb. oats, 1 lb. maize, 1 lb. barley. Approximately 73 lb. of food per bird was consumed, and the net profit was 10s. 7¾d. per bird.

	£	s.	d.
Total value of eggs ..	37	10	3
Total cost of food ..	10	17	5
Profit	26	12	10

Pen No. 7—*White Leghorns.*—These birds were allowed wet mash and mixed grain in the same proportions as fed Pen No. 6, except that the key meal was omitted. The amount of food consumed in both pens was the same; in Pen No. 7 the net profit was 8¼d. per bird more than that obtained from Pen No. 6.

	£	s.	d.
Total value of eggs ..	39	1	6
Total cost of food ..	10	14	3
Profit	28	7	3

Pen No. 8—*White Leghorns.*—Fed on dry mash, the proportions being 3 lb. bran, 6 lb. pollard, and 1 lb. meat meal. Mixed grain was fed in the afternoon in the proportions of 3 lb. wheat, 1 lb. oats, 1 lb. maize, 1 lb. barley.

The consumption of food was 7 lb. per bird more than in Pen No. 7 (wet mash); the profit per bird was 8¾d. less.

	£	s.	d.
Total value of eggs ..	38	5	0
Total cost of food ..	11	14	4
Profit	27	10	8

Pen No. 9—*White Leghorns.*—This pen was fed on dry mash in the proportion of 3 lb. bran, 6 lb. pollard, 1 lb. meat meal, and 1 lb. key meal. Free choice of grain was allowed, the order of preference being wheat, maize, oats, barley.

Although the food consumption, in this pen, was exceptionally low, the egg production was high, and the profit was higher than in any other pen.

	£	s.	d.
Total value of eggs ..	39	12	0
Total cost of food ..	8	4	7
Profit	31	7	5

Pen No. 10—*White Leghorns.*—These birds were fed on the free choice system, the various foods used being placed in separate hoppers and available at all times.

As was the case in Pen No. 1 (Australorps), the proportion of grain to meals consumed was high; the total amounts were 2,871 lb. grain, and 568 lb. meals. The order of preference was—meals: bran, pollard, meat meal, key meal; and grains: wheat, maize, oats, barley.

	£	s.	d.
Total value of eggs ..	38	13	4
Total cost of food ..	10	8	11
Profit	28	4	5

The average quantity of food eaten by, and the return from the 500 birds in the test were as follows:—

Breed.	Food Consumed per Bird.	Cost of Food per Bird.	Number of Eggs per Bird.	Value of Eggs.	Net Profit per Bird.
	lb.	s. d.		s. d.	s. d.
Australorps	75	4 5¼	165·2	14 5½	10 0¼
White Leghorns	70.1	4 2	177·0	15 5½	11 3½

Test No. 16.

WERRIBEE FEED TESTS—1ST APRIL, 1935, TO 31ST MARCH, 1936 (12 MONTHS).

Pen No. (Fifty Pullets in Each Pen).	Breed.	Food.									Total Food.	Cost of Food.	Total Eggs.	Value of Eggs.	Profit Over Food Cost.
		Bran.	Pollard.	Meat meal.	Key meal.	Dicalcic Phosphate.	Wheat.	Oats.	Maize.	Barley.					
		lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	£ s. d.		£ s. d.	£ s. d.
1	Australorps — Free choice bran, pollard, meat meal, key meal, wheat, oats, maize, barley	252	330	130	20	..	2,330	308	460	320	4,150	12 9 10	8,104	35 16 3	23 6 5
	Average	..	..	..	..	..	..	..	..	..	**83·0**	**0 5 0**	**162·1**	**0 14 4**	**0 9 4**
2	Australorps — Dry mash bran, pollard, meat meal, key meal; free choice, wheat, oats, maize, barley	188	378	63	63	..	1,602	367	332	266	3,259	9 12 9	7,991	35 5 3	25 12 6
	Average	..	..	..	..	..	..	..	..	..	**65·2**	**0 3 10¼**	**159·8**	**0 14 1¼**	**0 10 3**
3	Australorps — Dry mash bran, pollard, meat meal; mixed grain fed in litter	490	979	163	..	..	1,191	396	396	396	4,011	11 14 6	8,285	36 6 8	24 12 2
	Average	..	..	..	..	..	..	..	..	..	**80·2**	**0 4 8¼**	**165·7**	**0 14 6¼**	**0 9 10¼**
4	Australorps — Wet mash bran, pollard, meat meal; mixed grain fed in litter	384	769	128	..	..	1,191	396	396	396	3,660	10 14 3	8,602	37 4 3	26 10 0
	Average	..	..	..	..	..	..	..	..	..	**73·2**	**0 4 3½**	**172·0**	**0 14 10½**	**0 10 7**
5	Australorps — Wet mash bran, pollard, meat meal, dicalcic phosphate; mixed grain fed in litter	377	754	125	..	25	1,191	396	396	396	3,660	10 16 5	8,323	36 4 2	25 7 9
	Average	..	..	..	..	..	..	..	..	..	**73·2**	**0 4 4**	**166·5**	**0 14 5¾**	**0 10 1¾**
6	White Leghorns — Wet mash bran, pollard, meat meal, key meal; mixed grain fed in litter	349	700	116	116	..	1,191	396	396	396	3,660	10 17 5	8,693	37 10 3	26 12 10
	Average	..	..	..	..	..	..	..	..	..	**73·2**	**0 4 4¼**	**173·9**	**0 15 0**	**0 10 7¾**
7	White Leghorns — Wet mash bran, pollard, meat meal; mixed grain fed in litter	384	769	128	..	..	1,191	396	396	396	3,660	10 14 3	9,103	39 1 6	28 7 3
	Average	..	..	..	..	..	..	..	..	..	**73·2**	**0 4 3½**	**182·1**	**0 15 7½**	**0 11 4**
8	White Leghorns — Dry mash bran, pollard, meat meal; mixed grain fed in litter	489	977	163	..	..	1,191	396	396	396	4,008	11 14 4	8,789	38 5 0	26 10 8
	Average	..	..	..	..	..	..	..	..	..	**80·2**	**0 4 8¼**	**175·8**	**0 15 3½**	**0 10 7½**
9	White Leghorns — Dry mash bran, pollard, meat meal, key meal; free choice wheat, oats, maize, barley	172	346	57	57	..	1,298	315	316	205	2,766	8 4 7	9,103	39 12 0	31 7 5
	Average	..	..	..	..	..	..	..	..	..	**55·3**	**0 3 3½**	**182·1**	**0 15 10**	**0 12 6½**
10	White Leghorns — Free choice bran, pollard, meat meal, key meal, wheat, oats, maize, barley	208	196	146	18	..	1,916	338	405	212	3,439	10 8 11	8,569	38 13 4	28 4 5
	Average	..	..	..	..	..	..	..	..	..	**68·8**	**0 4 2¼**	**171·4**	**0 15 5½**	**0 11 3½**
	Totals—500 birds	..	..	..	..	..	..	..	..	..	36,273	107 7 3	85,562	373 18 8	266 11 5
	Averages	..	..	..	..	..	..	..	..	..	**72·5**	**0 4 3½**	**171·1**	**0 14 11½**	**0 10 8**

Notes.—Average price of eggs, 1s. ¼d. per dozen; food cost per dozen eggs, 3·6d.; food consumed per egg laid, 6·8 oz.; food consumed per bird per day, 3·2 oz.; cost of feed per bird per week, 1d.

Grading Tobacco

Preparation for Market

By G. E. Coghlan, Tobacco Expert

IN the course of this article it is intended to deal with the necessity for giving the utmost care to the grading and preparation of tobacco crops for market. Before proceeding with the salient features, a short discussion of the progress of the industry may be of interest.

It is well known and appreciated by the buyers that there has been a definite improvement in the leaf produced during the past ten years, both in colour and quality. Further, it is generally conceded that the leaf produced during the 1935–36 season is equal, if not superior, to that of any previous season. This may lead to the belief that the prospects of disposing of the present season's leaf is excellent, but consideration must be given to the fact that the crop is just double that of the two previous seasons. In the season 1933–34 the quantity of cured leaf disposed of was 1,470,784 lb., and in 1934–35 1,501,350 lb., while this season's crop is estimated at 3,000,000 lb. Although this quantity does not equal or exceed the quantity of leaf used annually in manufacture in Australia, it does help considerably towards building the annual production figures for the Commonwealth to a total exceeding the consumption figures. This actually provides the manufacturers with opportunities to exercise more discretion in their purchases than has been the case for several seasons past. Therefore, it must be realized that every care should be given to the grading and preparation of the crop for market if the utmost returns are to be gained from the season's efforts.

Going a little further in the consideration of the present status of the industry, it is felt that the advent of the "gas treatment" for raising seedlings free of blue mould has greatly enhanced the prospects of growers being able to raise greater quantities of leaf per annum and leaf of better quality. The introduction of "gas" will allow growers to place more reliance on their supplies of seedlings, and in so doing will cater to the full extent of their areas and plant. This method of raising seedlings will gradually overcome the experiences of the past when growers, having

Leaf being separated into its various colour grades.

undertaken the cropping of 20 acres, find that through failure of seedling supplies, or the subsequent death of many of the disease-tainted seedlings actually planted out, they have managed to establish half their areas only. Improvement in quality generally should develop also, as seedlings can be raised by the "gas" method at a time to suit the best planting and growing conditions in the district in which the grower is operating. This means that, as the method became more widely spread in its use, there would be no planting out taking place at periods which are really out of season, and the occurrence of late planted crops, and the ultimate low quality leaf raised from such crops, would gradually disappear. All these factors mean advancement and progress in the industry, and if greater production with better quality leaf does result from such progress it behoves growers to begin immediately to improve their methods of preparing the leaf for market, and grading is one very definite means towards this end.

Bulky and unattractive hands seen in a Melbourne factory.

As many growers are already aware, a certain line of co-operation was entered upon this season between the major purchasing company and the Department of Agriculture. This co-operation had as its objective the co-ordination of grading as required by the manufacturer and that which was looked upon as being desirable by the Department. Some days were spent in the factory by departmental officers, where numerous grades, actually every grade from each district as segregated in the factory, were worked over. The mixture of well-established grades found in any one sample was astounding. Instances of what was found in some samples of leaf examined and the re-classification of these grades are shown in the accompanying table :—

GRADING TOBACCO.

Original Grade.	Number of Grades Found.	Re-classification.
B.M.1 ..	5	B.M.1, B.M.2, B.M.2 (immature), I.B.2 (short bright)
B.M.2 ..	5	B.M.2, B.M.3, I.B.1, I.B.2, B.M.3 (immature)

It is obvious from the table that growers either do not appreciate what leaf constitutes a particular grade, or they are careless, and allow their colour grades to become confused with each other.

In the first case, viz., B.M.1, there were three distinct classes of leaf contained in the sample; the three classes being B.M.1, B.M.2, and "short" leaf. It might be suggested that there is not such a great difference between the two colour grades, B.M.1 and B.M.2, and that by bulking them together a better all-round price will be gained for the sample than if they are offered as separate lots. That, admittedly, has occurred in the past, but it must be obvious that the two grades would possess a varying manufacturing value. This, together with a general improvement in the leaf grown and a possible increase in production, coupled with a tightening up of the grades, means that any advantages gained in the past by making a good average sample will disappear. Thus, any grower who is not prepared to grade closer than he has done previously is going to be the loser.

With regard to that portion of the original grade which was re-classified as "short bright," it is often argued that this leaf is of the same colour and quality as the larger leaf, and that it all goes into the same line of manufacture. Growers who are of this opinion are entirely wrong, as such leaf is not of the same manufacturing value as that of

Showing roughly tied hands badly baled.

the same colour and quality, but which has length as well. The first difficulty which presents itself in respect to leaf designated as "short" is that the manufacturer has to pay a higher rate for "stemming" than is the case with the larger leaf. Further, "short" leaf does not possess the same characteristic ability to "cut" as does the larger leaf; that is, when short leaf is put through the cutting machines, it does not "hang together" the same as the larger leaf. This lack of ability to hang together is the cause of the short pieces or dust objected to by the smoker who "rolls his own" when he reaches the end of his tin of tobacco.

When a parcel of leaf is being put through the manufacturing process and has reached the "stemming" operation, employees doing this work demand higher rates, because the leaf being treated contains a percentage of shorts. Buyers are familiar with these troubles, and when purchasing a parcel of leaf containing shorts they place a lower value on it, a value which they consider will compensate the manufacturer for the higher cost of stemming that he may be forced to pay.

In the second case quoted the variations again were mainly a matter of colour, with the additional error that a certain percentage of "inferior bright" was included, a class of leaf which is of inferior manufacturing quality. Leaf which is included in this class re-acts in a similiar manner to that classed as short when passed through the cutting machines, and often due to its damaged and broken condition prompts those handling it to seek the higher "stemming" rate.

In addition to the incorrect grading on account of colour, a percentage of the leaf examined had to be re-classified as being "immature." Immature green leaf is the most objectionable type from the manufacturer's point of view, and must be excluded absolutely from all grades. This leaf never possesses the same smoking qualities as does a mature leaf; even that which has a green tinge at the completion of curing and loses this greenness by sale time does not smoke as smoothly as the fully-cured matured leaf. When grading, all green leaf and leaf showing traces of green should be placed to one side and "bulked down" at the conclusion of each day's operations. On completion of the grading of the whole crop this bulk may be worked over, and any leaf which has lost all traces of greenness can be graded out and made up into its respective grades. Any leaf still showing traces of green must be held until such time as it loses that colour.

Handing and Baling.

In "handing up" the leaf growers must aim at keeping the hands as uniform in size as practicable. Working with average size leaf, 14 to 16 leaves per hand are ample, and it will be found that if

Showing neatly tied hands well baled.

this number is placed neatly and closely together the resultant "hand" will be approximately 1 inch in diameter. A hand of this size should be aimed at in all grades of leaf, which naturally means that the number of leaves in a "hand" will vary according to the size of the midrib in the leaf being handled. All hands must be wrapped with a leaf of the same grade, and it is suggested that a much better appearance is given to the "hand" if the wrapper leaf is so folded that its face is to the outside. Neatness and evenness of "handing" give the buyer a good first impression and help considerably towards the leaf attaining its utmost value.

Care should be taken to bale the leaf in such a condition that it is neither too dry nor too moist. If baled too dry it will break during the pressing and deteriorate in value, while if too moist it will darken in colour under pressure, and the danger of it "heating," with ultimate loss, is greatly intensified. Bales should be kept under pressure for three-quarters of an hour to an hour if they are to retain their shape, and should not exceed 180 lb. in weight.

Summary.

In summarizing the foregoing remarks, there are a number of points which may be referred to as "Don'ts" and if they are adhered to an improvement in the grading of crops will result. They are as follow:—

(1) Don't mix the colour grades.

(2) Don't include long and short leaves in the same grade (a short leaf in an average crop will embrace those measuring from 8 to 15 inches in length).

(3) Don't include green leaf or leaf showing traces of green in the grade.

(4) Don't place broken leaf in any hands or grades composed of sound leaf. Broken leaf must be handed separately and placed in its own colour grade.

(5) Don't make the hands too big.

Young Farmers' Fallows

IN his report on the 1936 Fallow and Crop Competition conducted by the Murtoa Young Farmers' Club, the Judge, Mr. I. M. Tulloh, farm manager at Longerenong Agricultural College, said that the leading fallow shown by Mr. V. Schneider was an excellent one, gaining 98½ points out of a possible 100, one point being deducted on account of moisture content.

The soil of this fallow has a little sand showing through it and the last working had been made with a knife bar. The surface was even in tilth and the mulch had been reduced to an even depth of 1½ to 1¾ inches. Below this, the underlayers were very even, showing careful setting of implement tines, and consolidation was excellent and very even. Moisture was met with at 3½ to 4 inches and the consolidated surface showed no signs of cracking. On such a fallow, an autumn rain of some 75 points would link up with the conserved moisture and enable a good germination of weeds being dealt with before cropping. On a fallow with a deeper mulch and with the conserved moisture down 5 to 6 inches, a much heavier rainfall would be necessary before good cropping conditions would result. Further, in a wet cropping season, such a fallow as Mr. Schneider's could be worked to a shallow depth with the scarifier and hence later with the combine; whereas, on a fallow with a deep mulch, the autumn scarifying would, of a necessity, be deeper and a wet cropping season with the combine would mean heavy going and too deep a sowing.

A gratifying feature of the competition is the fact that several competitors claim to have increased the yield of their bulk crops by up to two bags to the acre by adopting, on their general fallow, the more careful methods which have shown to advantage on their exhibition section.

Results of the competition are as follow:—

V. Schneider, 98½; W. L. Schache, 96½; H. C. Petering, 94½; H. Webb, 94½; G. E. Schache, 93½; M. G. Schodde, 92½; V. Schache, 92; S. Moore, 91½; H. P. Herman, 90; W. W. Schodde, 89½; L. Sudholtz, 87½; R. Schultz, 85; P. Schache, 84, C. Sudholtz 83½; O. C. Petering, 78.

Orchard and Garden Notes

By Edward E. Pescott, F.L.S.

Florence Vaughan—a free-flowering Canna.

The Flower Garden.

A plant that should now be attended to is the Canna. This is a herbaceous perennial which, when grown in a mass, gives possibly a better effect over the flowering season than any other group of plants.

A brilliant garden-bed may be made by planting the tall varieties in the centre and the shorter ones in the front of the group. There are now dwarf varieties available, which grow only from 2 to 3 feet in height.

Cannas give the best results if the crowns are planted in a rich soil, well supplied with animal manure. The beds should be trenched to a depth of 2 feet, and the bottom of the trench filled with rich humic material. If animal manure is not available, any kind of garden litter or other suitable organic matter may be used. Then into the top soil, a fair supply of blood and bone-dust should be mixed, to give the necessary nitrogen.

Cannas require a good supply of water during the hot weather. With water and manure, a very brave show should be obtained and one which will last for many months.

Each canna stem should be cut down as soon as it has completed flowering to make way for fresh growths.

The Vegetable Garden.

Preparation should now be made for planting summer crops of vegetables. This will include pumpkins, marrows, cucumbers, and similar plants, all kinds of climbing and bush french beans, tomatoes, lettuce, radish, and other saladings, sweet corn, peppers, cape gooseberry, and many others.

The beds should be trenched and all humus and plant refuse, stable manure, bones, and the like dug into the trench. Wood ash and charcoal may be included in limited quantities, but coal and briquette ash, as well as that of coke should be avoided.

Nearly all these summer vegetable crops need protection from the cold, especially when they are young. It is very important that they should be covered all night, and for an hour after sunrise during very cold or frosty weather.

Rhubarb and asparagus plants should now be heavily manured. Root crops should be lifted if near maturity, and stored in the soil again. Care should be taken to lay them down as flat as possible.

The Orchard.

The time for re-working is about here: and growers should seek the advice and assistance of the Horticultural Branch of the Department, if they propose to re-work any trees during the current season. Officers will be appointed to instruct growers, and an early application should be made for their services. It is expected that the re-working campaign will be both extensive and vigorous.

Peach trees should be sprayed with nicotine sulphate as soon as the black peach aphis is noted. A good spray is one pint of nicotine sulphate and one gallon of white oil to eighty gallons of water.

Aphis on citrus trees should be given a similar spray. It may be necessary to repeat the spray about ten days later, if the whole of the aphis brood be not killed. In orchards where brown rot has previously occurred peach trees should be sprayed with lime sulphur, 1 in 9, just before the buds begin to swell. A second spray should be given with lime sulphur, 1 in 35, when the buds begin to show pink.

Soil Conditions at Bamawm and Ballendella in Relation to Citrus Growth

By F. Penman, M.Sc., Assistant Research Chemist

SUMMARY.—*Investigation of 93 citrus groves, constituting the entire citrus area of Bamawm and Ballendella, has been made, with special reference to soil conditions.*

Nine soil types have been defined, and their occurrences on the holdings examined have been delineated on the map (see Supplement Maps 1 to 3), together with demarcation of areas affected by waterlogging or by salinity.

The soil types are described, relations between them noted, and analytical features recorded. The mode of their formation is considered and their relations to the solonetz group of soils is indicated. Clay-pan structure is a feature of several of the type profiles, and the presence of a light permeable subsoil horizion is characteristic of the majority of the types. The last-named feature, together with the existence throughout the area investigated of a deep grey bed-clay of virtually impervious nature, makes these soils particularly susceptible to seepage effects. The topographic distribution of the soil types and the complexity of arrangement of occurrences of the different types also are conducive to development of water problems.

Apart from these disabilities inherent in the soils, the citrus of the Bamawm district stands to disadvantage in the scattered nature of the plantings and their frequent association with crops of high water demand, notably pastures for dairying.

On the evidence presented, free water is regarded as the factor dominating the relations between soil and citrus at Bamawm. The proportion of soils affected by free water is gravely high, and in view of the connexion between free water and salt accumulation it may be regarded as fortunate that these soils in general are moderately saline only. Under present conditions soil salinity is a secondary problem for the Bamawm citrus groves as a whole.

The great variability in citrus condition in the district and the general tendency to fall short of full vigour are described. The incidence of various factors on citrus condition is discussed, including free water, salt, low level of nutrition (especially from the aspect of available nitrogen), stocks, and disease. The influence of soil type at Bamawm is very marked. The soils intermediate in texture and general character are shown to be specially susceptible to waterlogging and salt accumulation. The effective life of citrus on these and the heavy soils under conditions which have prevailed at Bamawm is set below 20 years. It would appear that maintenance of citrus in good heart beyond ages of this order has been possible on soils other than the light group only under specially favorable local conditions and/or particularly good management.

It is suggested that the situation in the Bamawm citrus area demands both community and individual action. The principles underlying application of remedial measures are set out, with chief reference to water and salt problems, and the prospects of reclamation under various sets of conditions are examined.

THE areas known as Bamawm and Ballendella are adjacent parts of the Rochester Irrigation District, County of Bendigo, Victoria. The situation of these settlements with respect to the Murray, Campaspe and Goulburn Rivers, and to the chief towns of this region, is shown in Fig. 1. This sketch map sets out also the relation of the district to the Waranga Reservoir, from which its supply of irrigation water is drawn through the Waranga-Mallee Channel. The latter has, at Rochester, a capacity of approximately 1,800 acre feet of water per 24 hours. Of this amount, roughly one-half must be transmitted to districts west of Bamawm. The complete Rochester Irrigation District has an area of 176,000 acres, of which 55,000 acres are considered suitable for irrigation, which is effected by means of 396 miles of channel.

As shown on Map 1, the holdings which concern the present report are spread over four parishes, namely those of Bamawm, Ballendella, Rochester West and Diggora, the proportion in the last-named parish being very small. Current local practice uses the name "Bamawm" as a more or less comprehensive term to cover the whole area at present in question, with recognition of local zones such as "Bamawm Extension" at the north, "Lockington" at the west, and "Ballendella," designating the south-eastern portion, including part of Rochester West parish. This practice is followed in the present report wherever general reference is intended to the areas named, without strict attention to parish boundaries. Map 1 shows also that subdivision of the area has been carried out in "sections," A, B, and C, constituting Bamawm proper, D part of the parish of Diggora, E and F parts of parishes of Ballendella and of Rochester West respectively. Together with Bamawm Extension, these sections include all holdings concerned except a few in the south-central portion of the area which lie outside section boundaries.

General Description of Settlement.

Topography.—There are no outstanding physical features in this area. The general formation is that of plain country, relieved by low ridge or

Fig. 1.—Locality plan showing Bamawm and Ballendella.

"rise" structures with associated natural drainage. These ridges are almost certainly of aeolian origin. The whole area shows a general fall to the north, at an average grade of approximately four feet to the mile. The presence of two major, broken "ridge" formations in the area may be traced from the distribution of main irrigation channels in Map 1. It is emphasized that, even in the vicinity of the "rises," local relief is small, variations in level over a range of five feet in individual holdings being rare. The ridges and natural watercourses both show general north and south alignment and naturally the developmental works of the area, such as channels for irrigation and drainage, show similar orientation.

Geology.—The parent material for the soils of the district consists of sedimentary deposits, apparently of the late tertiary or recent age, the area being in fact part of an old flood plain of the Murray river system. Accounts of the digging of wells in the district show that there is about 80 feet of sediment, mainly of argillaceous character, overlying "drift."

The contribution of igneous and metamorphic rocks of the Eastern Highlands to the formation of the sediments of the Bamawm area is reflected in the frequent occurrence of mica in subsoils at and below a depth of about 30 inches (c.f. (7), p. 17). Occasional fragments of the feldspar also have been observed in these soils.

Climatic Conditions.—Rainfall and temperature data supplied by the Commonwealth Meteorologist are set out in Table I. The figures for rainfall represent results for 32 years at Bamawm, while the temperature figures for Echuca, the centre nearest to Bamawm for which such records are available, are means of 49 years' readings.

As might be expected, the climate of this district is intermediate between that of the Goulburn Valley and southern Mallee. Rainfall is more than three inches greater, and temperature 0.7° F. lower, on the average, than for Swan Hill.

Original Vegetation.—In its original state the greater part of this country was timbered. There was very little plain in the parish of Bamawm except to the north of a line joining the present Lockington railway station and the north-east corner of the parish. In the area thus specified, timber and plain country occurred in roughly equal proportions. With the exception of one or two small areas in Ballendella, where tongues of plain country intruded into the holdings, all the land with which the present report is concerned was timbered originally.

The bulk of the timber country carried grey box (*Eucalyptus hemiphloia*), particularly on the flats. The box stood in the form of thick forest, with individual trees of considerable size and with practically no scrub undergrowth and poor grass cover. The latter factor influenced early settlers towards going further west from Rochester to the plain country round Pine Grove. Box was so thick that costs in the '70's were about £5 per acre to clear, grub and make fit for the plough.

TABLE I.—METEOROLOGICAL DATA (MONTHLY AVERAGES).

—	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
Rainfall at Bamawm (inches)	0·87	1·03	1·21	0·96	1·74	1·87	1·69	1·55	1·78	1·49	0·95	1·17	16.31
Mean Temperatures at Echuca (degrees F.)	73·7	74·0	68·2	60·6	53·6	49·3	47·7	50·1	54·3	60·2	66·4	71·0	60·8

TABLE II.—ACREAGES OF DIFFERENT CROPS IRRIGATED, SEASON 1934–35.

—	Cereals and Fallow.	Lucerne.	Sorghums, &c.	Pastures.	Horticultural Crops.	Miscellaneous.	Total.
	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.
Rochester Irrigation District ..	7,744	15,362	711	24,741	1,750	839	51,147
Bamawm and Ballendella ..	1,232	5,150	187	5,383	1,369	171	13,490

Rising ground from grey box flats was covered typically by yellow box (*Eucalyptus melliodora*). while on the upper slopes particularly, this yellow box was associated with Murray pine (*Callitris robusta*). On the more definite ridges and some of the more extensive occurrences of light soils, there were often belts consisting almost entirely of close formations of pine. Such belts occurred in the south-west of the present Section B, the west and north-west centre of what is now Section C, in the present Section E and the holdings adjoining the west boundary of this section.

Accessory vegetation included buloke (*Casuarina lepidophloia*), fairly well distributed but with tendency to occur associated with pine, occasional needlewood (*Casuarina stricta*) and native cypress (*Exocarpus stricta*).

Conditions Subsequent to Clearing.—After portions of the area had existed for many years as outlying runs of large stations such as Wharparilla, selection and clearing of land proceeded for cereal cropping, which was so extensive in the Rochester district in general during the last 30 years of last century as to make it one of the leading wheat zones of Victoria at that time. Yields were good, crops approaching 30 bushels being reasonably common without the use of fertilizer and other aids now regarded as essential. It is of interest that plain country was regarded as little, if at all, inferior in cropping capacity to land previously under timber in this district.

The Waranga-Mallee channel was advanced through Rochester to the west in 1909, making possible the introduction of closer settlement in the Bamawm area. Several estates were acquired under the Closer Settlement Act and projects were initiated for irrigation of horticultural crops and of lucerne and pastures for dairying. In 1912, the first irrigation was carried out at Bamawm on a citrus grove.

Present Agricultural Activity.—Irrigated land in the Bamawm and Ballendella areas constituted approximately one-third of the total for the Rochester irrigation district in the season 1934–35,

Fig. 2.—Grey box at Bamawm.

as shown in Table II., taken from records of the State Rivers and Water Supply Commission.

Compared with the remainder of the Rochester district, the Bamawm and Ballendella areas show relatively less cereal cropping and pasture establishment, and greater proportions of lucerne and particularly of horticultural crops. To the last-named section Bamawm and Ballendella contribute the bulk of the district total and most of their orchard acreage is under citrus.

Recent History of Citriculture at Bamawm and Ballendella.

Since 1925 or thereabouts, troubles attributed by many to seepage have developed in this district. In the early incidence of these problems severe

damage leading to dying out of some of the lower-lying pasture areas was experienced and soon several citrus groves were affected to some degree. Investigations instituted by the State Rivers and Water Supply Commission showed in typical cases the presence of free water sufficiently close to the soil surface to cause injury to citrus, in some instances associated with salt in harmful concentration. Individual cases were examined as damage became manifest, and remedial measures were undertaken in accordance with the requirements of the particular areas concerned. During the last decade considerable outlay has been made on some groves for drainage systems, both tile and open cut, and certain provisions for outfall facilities have been made by the Water Commission and modified as occasion demanded. In general, however, the spread of unthriftiness in the citrus groves of the district had not been arrested.

This was the situation faced in 1933 by the Bamawm Citrus Investigation Committee, a departmental body then constituted to examine conditions at Bamawm in relation to citrus and to suggest remedial measures as a guide to future administrative action. This Committee comprised Messrs. J. M. Mathew, B.M.E. and I. B. Hughes of the State Rivers and Water Supply Commission and Messrs. W. R. Jewell, M.Sc. and F. M. Read, M.Agr.Sc. of the Department of Agriculture. In November, 1933, Mr. H. E. Harding, B.Sc. (Calif.), replaced Mr. Hughes as District Engineer for the Water Commission at Rochester and therefore took his place on the Committee. Mr. S. P. Bromfield has represented the Closer Settlement Commission in recent work of this body. In July, 1933, the Committee issued a report giving the chief reasons for conditions existing at Bamawm and a general indication of remedial methods. It pointed out that more detailed information was essential before individual blocks could be considered, and suggested that work along the lines of established soil survey practice should be carried out.

In July, 1934, systematic soil survey was commenced at Bamawm. The soil survey was under the general direction of the writer, and the detailed work was carried out by two field parties under Messrs. R. H. Fowler, M.Agr.Sc. and J. R. Freedman, B.Agr.Sc. This work was designed to reveal in detail the situation on each citrus grove in the settlement, with regard to condition of citrus and its relation to soil types and their distribution, salinity, waterlogging, possibilities of drainage, &c. In addition to detail on individual holdings, the broadest possible information concerning the citrus groves as a community was sought with the object of securing data useful in the planning of the works of the Water Commission, and in linking individual problems with the situation in the settlement as a whole. Particular attention was given throughout to drainage considerations, the construction by the Water Commission of a general scheme of drainage works for the district having been in progress since May, 1934, under relief work conditions. During the progress of soil survey, information concerning soil conditions in particular areas has been utilized by the Water Commission in these community works and by the Closer Settlement Commission in relation to individual holdings.

When sufficient data was available, a report on the soil work was given to the Investigation Committee in April, 1935. In view of the fact that many of the suggestions made to the Committee concerning individual groves depended to considerable extent on the existing condition of the citrus, it was decided to supplement the survey records of tree health by a comprehensive horticultural inspection. This was carried out in May, 1935, by Mr. J. L. Provan, B.Agr.Sc., Horticultural Research Officer of this Department, accompanied by the writer. Opportunity was thus given for detailed investigation of all the citrus of the settlement at the one season of the year and in the light of information accumulated during the survey. In June, 1935, the Bamawm Citrus Investigation Committee issued a report giving detailed recommendations for administrative action respecting each holding. Copies of the portions of this report relevant to each grove were made available to individual growers through the Closer Settlement Commission.

Laboratory investigations essential for adequate description of the soil situation in the settlement have been conducted since the completion of field work. The present report is given as a comprehensive record embodying all suitable information available concerning soil conditions at Bamawm and Ballendella and their relation to the growth of citrus, with brief consideration of other factors contributing to the general position of citriculture in the district.

Scope of Soil Survey.

Detailed examination of 93 citrus groves was made in this work, involving approximately 920 acres. The latter represents about 12 per cent. of the citrus acreage of the State, although the actual proportion of trees in the Bamawm area to the State total probably lies nearer 10 per cent.

As shown on Maps 1 to 3, the holdings concerned are scattered over a large area, extending about eight miles north and south, and seven miles east and west. Plantings vary in size from areas of about one acre to groves larger than 40 acres, the average size being approximately ten acres. The contour range on citrus groves is from 333 to 365 feet, but variations on any particular grove rarely exceed 4 feet.

It will be observed that the holdings examined constitute but a small proportion of the area over which they are scattered. It is not suggested that the findings of this survey are representative of conditions over the whole Bamawm Estate, as the citrus plantings have tended to follow the higher lands adjoining the distributing channels. Although the proportions of the different soil types over the whole area are doubtless very different from those formed in the citrus groves only, it appears unlikely, from observations made, that soil types differing substantially from those described in this report occur at Bamawm. Most of the plain country for example, appears to conform to one or the other of the heavy soils found in citrus areas.

This explanation is rendered necessary by the fact that it is convenient for the present purpose frequently to refer to "the area" and "the soils of the area," when reference is intended solely to the citrus holdings examined and not to the Bamawm area generally.

The closest approach to bulk planting is in Section C, which carries almost one-third of the citrus of the Bamawm district. The distribution of citrus throughout the areas is shown in Table III.

TABLE III.—CITRUS IN INDIVIDUAL SECTIONS AS PERCENTAGE OF TOTAL FOR BAMAWM AND BALLENDELLA.

	Section.					
Bamawm Extension.	A.	B.	C.	D.	E.	F.
% 12	% 13	% 25	% 31	% 0.2	% 11	% 7

Nature of Citrus Planting.

Information obtained by the Horticultural Division of this Department in 1933, with regard to citrus plantings, is given in Table IV. The group aged from 5 to 15 years, at that time, constitutes the bulk of the planting. About half the total are Washington Navels, with Valencia Lates and lemons, in roughly equal number, dominant among the remainder. In the more recent plantings, the Table shows that notable displacement has occurred towards Valencia Lates, lemons, and grapefruit, as compared with Washington Navels.

TABLE IV.—CENSUS OF CITRUS TREES IN BAMAWM DISTRICT, 1933.

Variety.	Under Five Years.	Five to Fifteen Years.	Over Fifteen Years.	Total.
Washington Navel	1,953	17,981	12,767	32,701
Thompson Navel	200	75	630	905
Other	..	150	193	343
Valencia Late ..	2,462	8,539	2,786	13,787
Commons ..	25	2,574	951	3,550
Grapefruit ..	570	596	20	1,186
Lemons ..	1,582	8,248	4,579	14,409
Mandarines ..	..	247	130	377
Total ..	6,792	38,410	22,056	67,258

SOILS OF THE AREA.

Description and Classification.

Under casual observation, the appearance of the soils of the Bamawm area suggests reasonable uniformity. The surface colour falls within various shades of brown, frequently tending to red, while the range in surface texture is not wide when the area involved is considered. These features combine with the topography to give an impression of general uniformity, relieved occasionally by the obviously light soil of a "pine rise" of more prominent nature than usual, or by relatively heavy and dark soil surrounding a drainage gulch through a flat.

Systematic examination has revealed, however, that these soils are unusually complex in their variety and distribution, variation in subsoil character being very marked.

As a result of the survey, the citrus soils of Bamawm and Ballendella have been classified into nine types, to each of which has been assigned a name expressive of the texture of its surface horizon and with some degree of local significance. It is mentioned here that, because a soil type has been called, for example, Ballendella Loam, it is not implied that it occurs only at Ballendella, but rather that it is of greater relative importance among the soils of its class in the Ballendella area than elsewhere. In order to facilitate discussion in following sections of this report, each soil type has been given a number also.

TABLE V.—SOIL TYPES OF BAMAWM AND BALLENDELLA.

Type Number.	Type Name.	Relative Area.	Distinguishing Features.	Group.
		%		
1	Lockington Sand ..	7	Deep sand	Light
2	Bamawm Sand	8	Moderately deep sand, lower horizons heavier than in Type 1	
3	Bamawm Extension Sandy Loam	16	Shallower surface and consistently heavier than Type 2 throughout the profile. Has horizon of light texture below approximately 2 feet depth	Intermediate
4	Bamawm Loam ..	11	Similar to Type 3, except for heavier surface ..	
5	Ballendella Sandy Loam	10	Similar to Type 3, except that there is no light zone in the deeper subsoil	
6	Bamawm Fine Sandy Loam	13	Similar to Type 5, except for nature of surface soil	
7	Bamawm Sandy Loam ..	10	Similar to Type 3, except for heavier clay of the upper subsoil	
8	Ballendella Loam ..	17	Similar to Type 7, but heavier throughout profile	Heavy
9	Lockington Loam ..	8	Similar to Type 8, but no pronounced lightening of texture in deeper subsoil	

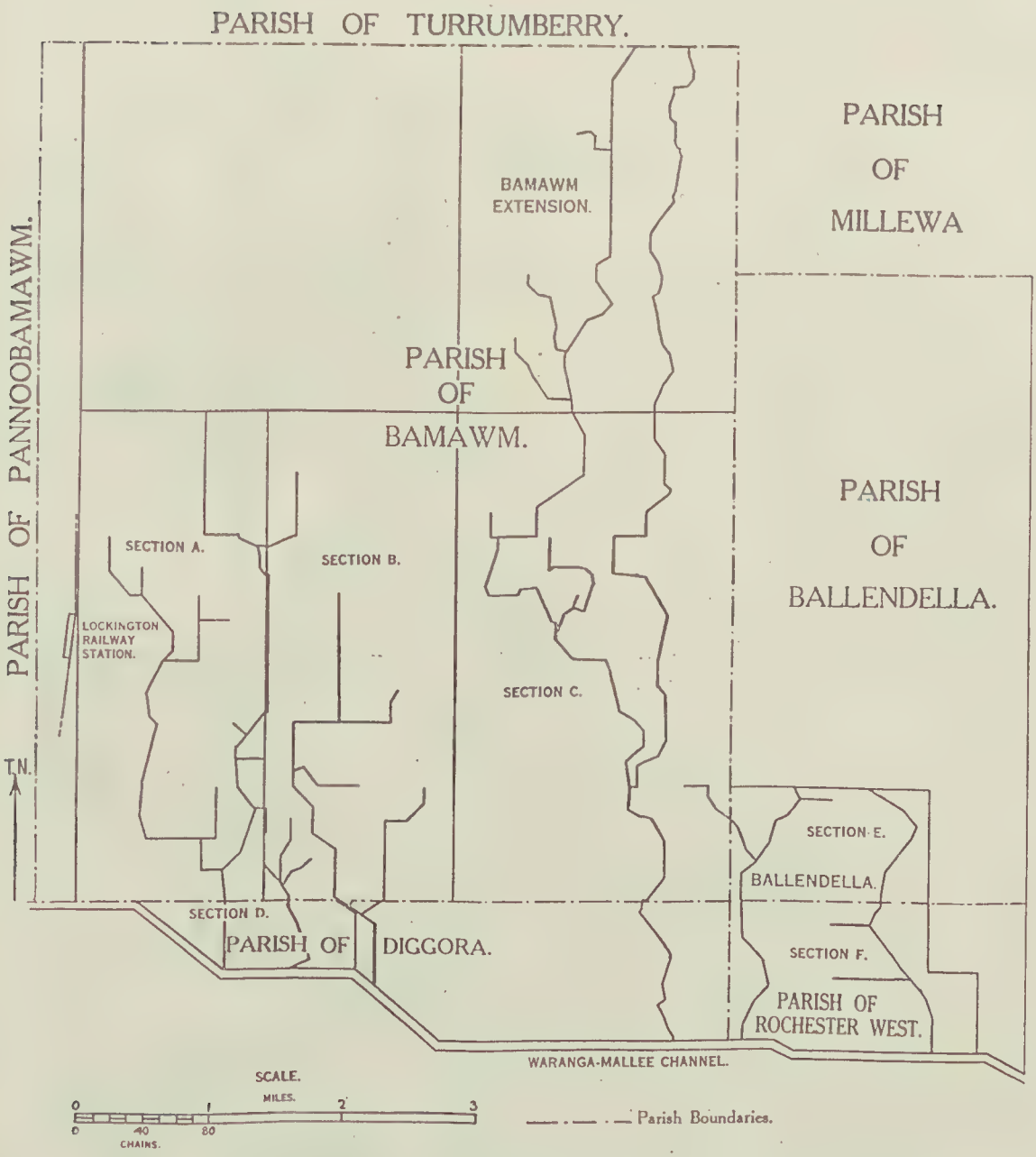
The soil types of the area, distinguished in the manner described are set out in Table V, with brief statement of the characteristic features of each type, and its relative importance with regard to area covered, expressed as percentage of total area surveyed. In this Table the types are grouped into three main divisions of light, intermediate, and heavy soils. This grouping, while based on texture differences between the profiles, holds for many properties in addition to mechanical constitution. Reference will be made later to aspects of the general soil situation in which "intermediate" soils act as linkages between the "light" and "heavy" groups.

The light group is distinguished by considerable depth of sand overlying horizons which do not show heavier texture than that of a clay loam or light sandy clay. Classification of the remaining soils into intermediate or heavy groups is dependent upon the extent of clay accumulation in the upper subsoil and on the depth below the surface at which such accumulation becomes manifest. Thus "heavy" soils attain at least the texture of a medium clay at or above a depth of 12 inches, while the "intermediate" types are no heavier than light clay within this limit.

Table V shows that subdivision of the light group into two soil types is effected on differences in degree of lightness rather than on any specific feature in either type. Within both intermediate and heavy groups, classification into the types shown in the Table was made according to the texture of the surface soil and the nature of the deeper subsoils, a special differentiating feature being the presence in some types of considerable depths of material of relatively light texture in this latter portion of the profile.

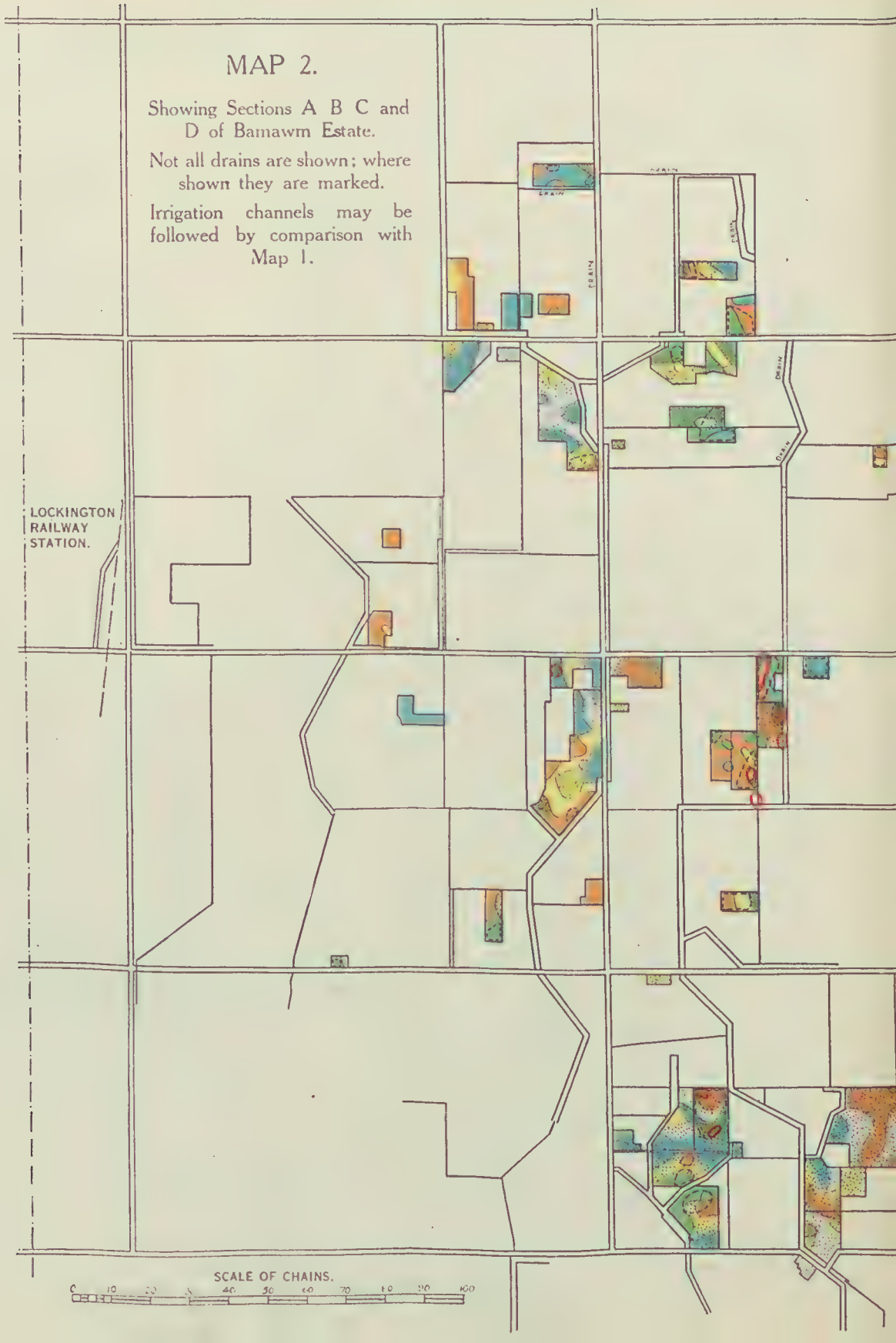
The figures given in Table V. show that the light group of soils cover 15 per cent. of the Bamawm citrus area, the heavy soils 35 per cent., while intermediate types account for the remaining 50 per cent. Thus 85 per cent. of the area in question is covered by soils showing zones of clay accumulation at no great depth below the surface. Roughly half of the area carries sandy or sandy loam surfaced types, the remainder being of loam or fine sandy loam surface. As will be mentioned later, many of these latter soils tend to silty character. Types with notable lightening of texture in the deeper subsoils as compared with overlying horizons (Types 1 to 4, 7, 8) constitute 69 per cent. of the area surveyed.

The Bamawm soils have a common feature in the presence of a grey and yellow mottled clay in the deep subsoil. There are local variations in the depth at which it occurs, in colour, sometimes showing variations to red or brown, and in texture, often to pronounced silty character and occasionally including within it sub-zones of sandy or gravelly nature. In general, however,



MAP 1. Showing Parish and Section Boundaries and Irrigation Channels distributing from the Waranga-Mallee Main Channel.

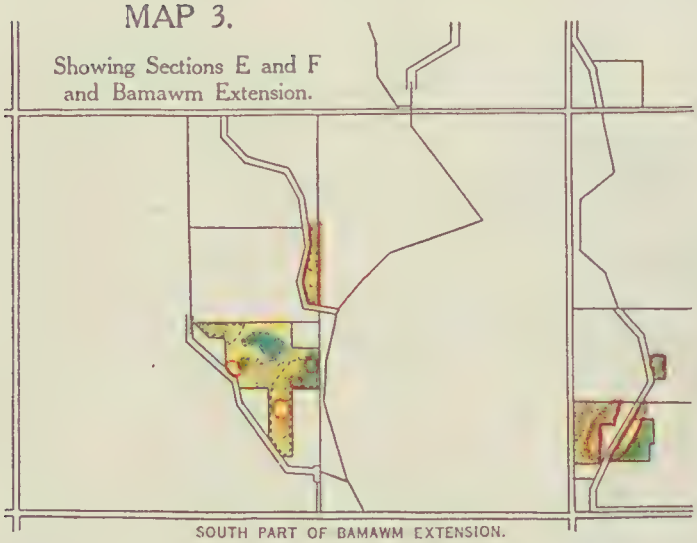
On the larger Scale Maps 2 and 3, Sections A B C and D are included on Map 2 and Sections E F and Bamawm Extension on Map 3.


MAP 2.
Showing Sections A B C and D of Bamawm Estate.
Not all drains are shown; where shown they are marked.
Irrigation channels may be followed by comparison with Map 1.
PARISH OF PANNOOBAMAWM.
LOCKINGTON RAILWAY STATION.
DRAIN
SCALE OF CHAINS.
0 10 20 30 40 50 60 70 80 90 100

PARISH OF BALLENDELLA.

MAP 3.

Showing Sections E and F and Bamawm Extension.



this clay may be regarded as of reasonably uniform character in that it exists without essential change throughout the area, forming a common bed for the soil horizons of agricultural interest. Reference will be made to this material as "deep grey clay" in following sections, although it is typically grey and yellow mottled. As indicated in the note on geology of this area, argillaceous sediment of this general type appears to persist to depths of the order of 80 feet. In the present work this clay was examined in various parts of the area to depths ranging to 15 feet.

Individual Soil Types.

Description of individual soil types will be given by reference to diagrammatic presentation of the features of representative profiles of each type as shown in Fig. 3, and to analytical results for specimen profiles as set out in the Appendix. Fig. 3 shows profiles to 72 inches; where this is insufficient to reach the deep grey clay, description of the intervening zones is given in the text. Depth to the deep grey clay is called "depth of profile."

Type 1. Lockington Sand.—This is the lightest soil type of the area, being distinguished by considerable depth of very light surface soil, succeeded by horizons in which clay accumulation has proceeded to relatively slight extent. It shows at least 20 inches, but often up to 40 inches or more, of surface sand. In typical profiles, after the surface horizon has given place to rather heavier zones as shown in Fig. 3 and the Appendix, a light horizon is again encountered at depth. This may persist to about 8 feet, then merging through transition zones to the deep grey clay at about 9 feet. In the specimen profile, clay percentage did not rise above 23 per cent. in any horizon to a depth of 6 feet.

Type 2. Bamawm Sand.—The close relation of this type to Lockington Sand is evident from the illustrative profiles. The distinction lies in the tendency to lesser depth of profile in Bamawm Sand and in the fact that clay accumulation in certain zones of the subsoil has proceeded to definitely greater extent. Thus in the specimen profile clay content reaches 32 per cent. at 22 to 43 inches.

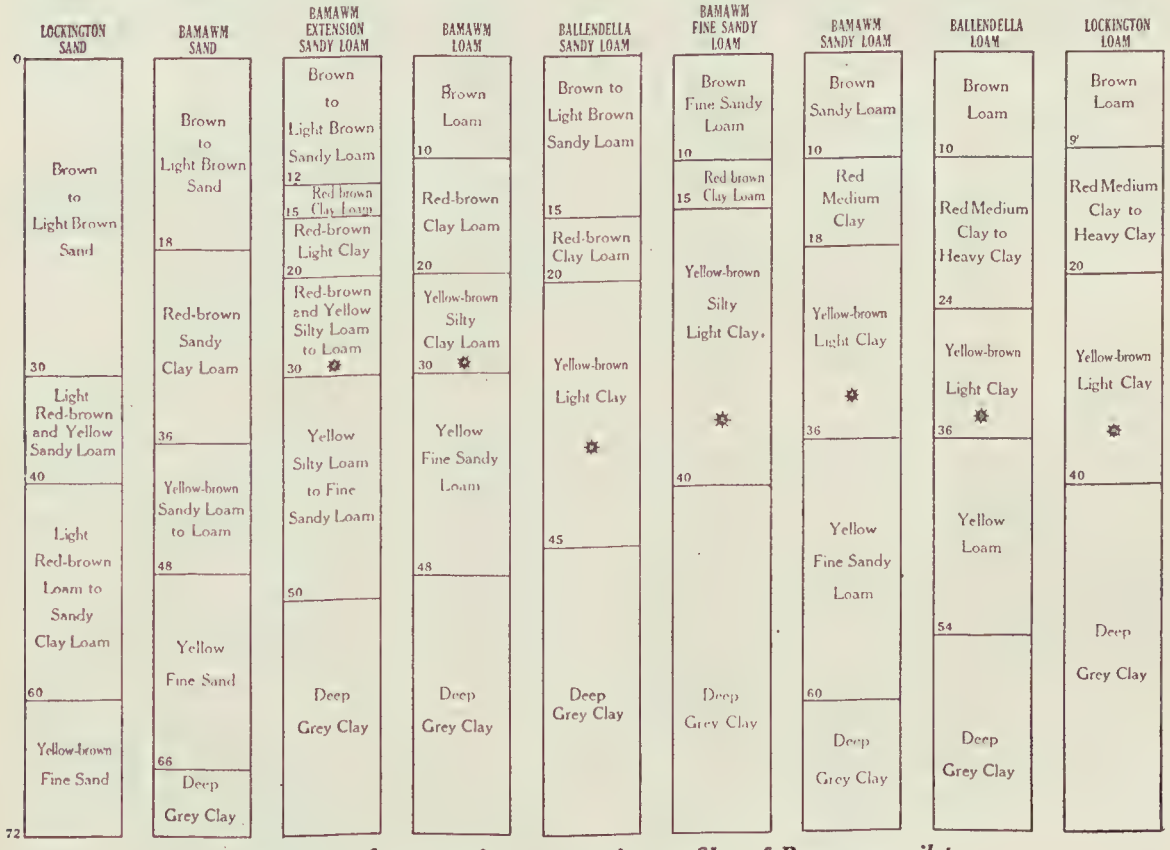


Fig. 3.—Showing features of representative profiles of Bamawm soil types.
Depths are shown in inches. * Marks horizon of lime accumulation.

In this type, surface sand rarely exceeds 24 inches in depth and the change to the underlying horizon of clay accumulation is in general more definite than in Lockington Sand. The grey clay of the deep subsoil may be encountered at from 5 to 7 feet, often following transition zones of yellow or grey light clay beneath the yellow fine sandy horizon.

Type 3. Bamawm Extension Sandy Loam.—As noted in Table V this soil occurs to roughly double the extent of either of the light group, being one of the major types of the area. In this profile, surface soil, typically a sandy loam, is rarely deeper than 18 inches, so that, as a rule, texture reaches that of clay loam, or light clay, within a depth of 20 inches. This consistently heavier texture and decreased depth of profile are the chief features setting this type apart from the light group.

Shallow transition zones between surface soil and the horizon of clay concentration are common in this type. This is illustrated in the specimen profile recorded in the Appendix.

Type 4. Bamawm Loam.—This soil is distinguished from those already described by the heavier character of the surface horizon, which is typically a loam tending towards silty loam. It is made clear in Table V. and Figure 3, that, apart from this feature, this type is closely similar to Bamawm Extension Sandy Loam.

This similarity is evident from the analysis recorded in the Appendix which shows also the distinction between the surface horizons 3986 and 3995 in the proportions of the finer fractions clay and silt. The profile listed in the Appendix is not quite representative of this type in its general shallowness and the rather heavy nature of the zone 22 to 36 inches.

Soils of this type often occur in association with Type 3, and it is important to recognize the differences between them in relation to irrigation and cultivation, due to the differences in surface character.

Type 5. Ballendella Sandy Loam.—The nature of the profile in this type is shown by Fig. 3 and the analyses recorded in the Appendix. In contrast to Types 1 to 4 above, the illustrated profiles show that there is no tendency towards lighter texture below the upper clay zones, indeed the sequence of clay percentages in the Appendix shows definite change in the opposite manner.

Type 6. Bamawm Fine Sandy Loam.—The soils of this type constitute the fine-textured counterparts of Type 5 soils, as far as surface horizons are concerned, other horizons being generally similar, as shown in Fig. 3. The relation between Types 5 and 6 is thus comparable with that between Types 3 and 4. The difference is evident in physical constitution between the surface sample 4015 of this type, as shown in the Appendix, and the corresponding sample 4034 for Ballendella Sandy Loam, particularly with regard to content of coarse sand. Surface soils of this type include loams and silty loams as well as fine sandy loams.

Type 7. Bamawm Sandy Loam.—This is the lightest of the three heavy types of the area. Its inclusion in the heavy group rests entirely on the extent of clay accumulation in a zone relatively close to the surface, the remainder of the profile being relatively light. On this account, this soil has close relations with certain of the lighter types, especially Bamawm Extension Sandy Loam. This is illustrated by the representative profile in Fig. 3 and by the analyses in the Appendix. The latter show the sharp change in clay content from the surface horizon to the claypan, a feature common to all members of the heavy group, as is also the "smooth," very compact nature and generally strong red colour of this clay under field conditions.

In this type the yellow fine sandy zone of the deeper subsoil is often extensive, frequently merging through silty clay loam, or light clay of grey and yellow colour to depths of the order of 8 feet, before the deep grey clay is reached.

Type 8. Ballendella Loam.—This soil covers 17 per cent. of the area surveyed and is thus the most important individual type in extent. Fig. 3 and the Appendix illustrate the relation noted in Table V between this soil and Type 7, the profile here being more shallow and heavier throughout. The essential difference between the two types lies in the heavier surface of Ballendella Loam.

Type 9. Lockington Loam.—As illustrated in Fig. 3 and the Appendix the profile of this type, the heaviest of the area, is more shallow than for Ballendella Loam and does not show any marked change to lighter texture below the red clay-pan.

This type is therefore linked with Types 5 and 6 in having no "permeable" subsoil zone. It is more closely related to Type 6 in general profile character but, of course, is heavier throughout.

Differentiation Within Surface Horizons.

It will be noted from the Appendix that all surface horizons, except one in which the total depth of this horizon is only 6 inches, have been differentiated into two depth zones. This may not appear to be justified on the analyses recorded

there because of quite slight differences shown in most cases between the two samples. This sub-division is based on definite structural differentiation within the surface horizons. From observations made throughout the course of this work these differentiations, though slight, are fairly general throughout the area.

These distinctions are of two kinds. In the light group of soils differentiation is based entirely on the presence of an upper zone of slight humus accumulation, commonly of a depth of about 9 inches. In the intermediate and heavy soils this effect occurs also in the upper zone but there is an additional factor in tendency, in the lower zone, to cementation or "hardpan," presence of streaky bleached areas and tendency to formation of ferruginous pellets. In most cases the last effect extends only to presence of rounded grains of the size of coarse sand, but in some instances the further development to buckshot has occurred. Types 3 and 4 show these features to less degree than Types 5 to 9.

The importance of these effects in the lower zones of surface horizons, lies in the fact that they may be attributed to periodic, temporary waterlogging in these zones due to delayed penetration of water into the horizons of clay accumulation. In this sense of marked difference in water relations between the surface horizon and that underlying it, all the intermediate and heavy soil may be regarded as "claypan" soils, the intensity of the effect naturally being greater in the heavier soils. Thus many of the Bamawm soils show the presence in a mild form of a feature which is carried to considerable extent in certain Goulburn Valley soils (2).

Variations Within Individual Types.

Description of the soil types has been based on representative or typical profiles. Actually, the soils examined vary over such a wide range of physical constitution that considerable elasticity is demanded in some of the types with regard to the specifications to which certain horizons must conform. This refers specially to the light subsoil horizons in Types 1 to 4 and 7 and 8. In all these cases the material concerned may be "yellow fine sandy loam," open, permeable, rather "floury" or "drifty" in character, often described as "yellow micaceous silt." For purposes of classification, any soil material occurring in this depth-zone with field properties indicating relatively high permeability was included in this general class. Thus stone and gravel (both quartz), various combinations of gravel, sand (both coarse and fine) and silt were included. In some cases, especially in Types 3, 4, and 8, it was necessary to include also, material which satisfies the essential requirement of those profiles in being relatively permeable, but rising in texture as high as loam to clay loam.

Apart from subsoil variations those in surface soils of certain types are the most notable. In some of the sandy-surfaced types, occurrences of gravelly and coarse sandy variants were included. Each of the heavier-surfaced types varies in surface texture over the range fine sandy loam, loam, silty loam.

Occurrence of Calcium Carbonate.

As in most of northern Victoria, calcium carbonate when present in these soils occurs both as limestone rubble and as soft lime. The heavy group of soils is typically lime-bearing, while in the intermediate soils there is roughly an even chance of encountering lime in visible amount in the upper horizons. The light soils in typical cases do not show lime in appreciable quantity.

The points are illustrated in Table VI which also distinguishes between Bamawm Fine Sandy Loam and the other intermediate soils from this point of view, setting it apart towards the heavy group.

Although massive aggregations were found in some cases, lime rubble when present in these soils is usually in the form of nodules of less than half-inch diameter. While usually less in amount than about 8 per cent. of the field soil with which it is associated, there is a tendency when rubble is present at all, for heavier accumulation in certain types, notably Bamawm Sand, Ballendella Sandy Loam and Bamawm Sandy Loam.

As might be expected, the depth at which rubble accumulation begins in the profile is greater, and shows greater variation within each type, in the lighter soils. Among the intermediate and heavy types, those with sandy surfaces show definite tendency to lime concentration at greater depth than in the heavier-surfaced soils. Thus analysis of the survey data discloses that Types 3, 5, and 7 show chief lime zone at 26 to 30 inches, compared with 21 to 25 inches for Types 4, 6, 8, and 9. This, like the first effect mentioned in this paragraph, may be attributed to differences in inherent leaching facilities.

Again, Table VI. shows that under local conditions all soil types have tended to accumulate lime in the appropriate horizons in the form of rubble rather than to show appreciable quantities of soft lime. This tendency is carried furthest in some of the heavier-surfaced types, and may be

TABLE VI.—PERCENTAGE OF BORES IN EACH TYPE SHOWING LIME.

—	Lockington Sand.	Bamawm Sand.	Bamawm Extension Sandy Loam.	Bamawm Loam.	Ballendella Sandy Loam.	Bamawm Fine Sandy Loam.	Bamawm Sandy Loam.	Ballendella Loam.	Lockington Loam.
Rubble and/or Soft Lime present	8	28	50	51	51	65	77	75	84
Soft Lime present	2	2	12	10	17	10	24	12	10

related to greater variation in moisture conditions under normal seasonal change.

This discussion of lime occurrence has been concerned with amounts detectable in the field. As shown in the Appendix, many horizons contain amounts of calcium carbonate of which the presence is revealed only by analysis. Profiles showing relatively small total amounts of lime however, exhibit definite tendencies to concentration in the particular horizons appropriate to the soil type. This is shown by the results for "calcium carbonate in fine earth" in the Appendix, which in each profile tend to maximum figures in the zones in which rubble accumulation is a normal feature. The indication is that deductions from information based on occurrences of lime in visible form may be extended to cover the more general situation concerning the distribution of calcium carbonate in any form.

It is more important to note the structural position of lime in these profiles. Although it may occur scattered through various zones, even to some extent in the deep grey clays, the typical position for lime accumulation in all types is in the horizon immediately beneath the major clay accumulation or in the lower portions of this horizon itself.

It would appear from the information presented in this report and from previous analytical records for Bamawm soils that calcium carbonate is present to some extent in the profiles of all soils of the area. The fact that it is present in such small amount as to escape field detection in a considerable proportion of profiles, especially in the lighter types, and the extent of its occurrence when present, show that calcium carbonate in these Bamawm soils is a feature of considerably less prominence than in Mallee soils, although its role in profile formation may be no less important.

Laboratory Investigations.

MECHANICAL ANALYSES.

Reference has been made to mechanical analyses in the Appendix of samples from specimen profiles of the nine soil types. Attention is now drawn to certain features of these results, in comparison with other soils of northern Victoria. Relatively high silt proportions, and dominance of fine sand fraction, in many of these soils link them closely with Goulburn Valley types and distinguish them from Mallee soils in general. It is proposed to examine the relations between these soils of Bamawm and others of the north in a later report.

The Appendix shows that silt assumes unusual importance in certain horizons of all types except the light group. While they have been described as being typically loams, many of the heavier-surfaced soils—Bamawm Loam, Bamawm Fine Sandy Loam, Ballendella Loam and Lockington Loam—approximate to true silt loams, as for samples 4009 and 4010 in the Appendix. In certain of the subsoils definitely silty nature is shown, as for samples 4018, 3990 and 3992 and particularly 4033.

The proportions of fine sand and of silt are such as to give a somewhat unbalanced character to the soils of the area. They have a somewhat unbalanced constitution. Coarse sand is of small importance except in Lockington Sand, which differs strikingly from all other types in its coarse character, and to a lesser degree in the other light-surfaced soils, Types 2, 3, 5, and 7. In these latter, there is sufficient coarse sand to exert considerable modifying effect on the texture of the surface soils.

The situation with respect to sand fractions is brought out by the ratio of coarse sand : fine sand in the Appendix. Lockington Sand is outstanding, with ratios of the order of 1·0 at all depths, while for the light-surfaced types enumerated above, ratios may rise to 0·4 for the surface horizon, falling with depth in the profile to 0·1 or less. Among the heavier-surfaced soils, ratios for Types 4, 6 and 9 are less than 0·05 for all horizons except some of the deepest subsoils. Type 8 is unusual as a heavy soil showing a ratio approaching 0·1 for the surface horizon. Between the related Types 5 and 6, marked differences are shown to considerable depth, Type 5 containing greater proportions of coarse sand.

Figures for "gravel and rubble" in the Appendix show that this fraction rarely reaches notable proportions unless limestone rubble is present. Exceptional occurrences are those of strata of quartz stone and gravel as in certain subsoils, particularly at Ballendella, and some isolated areas of gravelly-surfaced soils as at the north of the Lockington region. Ferruginous pellets in the form of buckshot are not of such importance in these soils as in those of the Goulburn Valley, nevertheless they are often present to some degree in representatives of the intermediate and heavy groups, as in samples 4021 and 4026. The deep grey clay sometimes carries buckshot. In addition, the coarse and fine sand fractions consist partly of ferruginous grains, although the bulk of these fractions is usually quartz, often with mica and occasionally with feldspar. Such ferruginous grains occur in the light soils only in the deeper horizons, but may occur throughout the profiles in the heavier types. The significance of the occurrence of such ironstone pellets in lower portions of surface horizons has been discussed in a previous section. In general, their presence is associated with conditions of impeded drainage in the horizons in which they occur (2).

The above discussion is not intended to minimize the paramount importance of the clay fraction in determining the mechanical properties of these soils. This has been made clear by reference in previous sections to the system of classification of these soils as based on clay content and to the striking changes in clay content within the profiles of individual types, giving rise to "pan" structures, &c. As in most other areas, the amount and the nature of the clay are the most important factors concerned in the physical properties of these soils.

Total Nitrogen and Hydrochloric Acid Extract.

Table VII. sets out results of analyses of surface samples of the representative profiles of the nine soil types.

The low phosphoric acid and total nitrogen values are of the general order prevailing in northern districts. There are good reserves of total potash and moderate amounts of lime and magnesia, except that the sample of Ballendella Loam has relatively poor total lime for a soil of its nature. These results in general are of normal character for soils of this region, with close resemblance to Goulburn Valley analyses.

While comparison between soil types is hardly acceptable on the data presented in Table VII. because of complications due to different depths of sampling, differences in cultural practice on individual groves, &c., the figures show the usual tendency towards higher values in the heavier soils, an effect more notable in the case of potash

Table VII.—Chemical Analyses of Soils.

Figures are Parts per 100,000 *of Dry Soil.*

Type.	Sample Number.	Depth (Inches).	Nitrogen (N).	Phosphoric Acid. (P_2O_5).	Potash (K_2O).	Lime (CaO).	Magnesia MgO).
Lockington Sand	4005	0 to 8	68	37	270	189	162
Bamawm Sand	4000	0 to 9	51	55	241	198	156
Bamawm Extension Sandy Loam	3986	0 to 7	89	27	375	213	204
Bamawm Loam	3995	0 to 6	80	40	451	249	254
Ballendella Sandy Loam ..	4034	0 to 5	81	29	325	234	171
Bamawm Fine Sandy Loam ..	4015	0 to 6	62	67	465	291	234
Bamawm Sandy Loam	4027	0 to 6	97	64	385	285	203
Ballendella Loam	4022	0 to 4	112	54	507	204	260
Lockington Loam	4009	0 to 5	97	51	438	240	237
Group.							
Light	..	0 to 12	42	24	76	174	189
	..	12 to 24	28	27	292	214	318
Intermediate	..	0 to 9	49	35	190	208	226
	..	9 to 15	31	39	295	241	447
	..	15 to 24	25	33	362	616	510
Heavy	..	0 to 6	67	46	319	169	287
	..	6 to 12	44	38	391	251	515
	..	12 to 24	34	51	446	767	742

than for the other constituents. Differences between the three groups of soil types of the area are brought out more effectively by the lower portion of Table VII. These latter samples are representative of the three broad divisions of Bamawm soils, taken prior to the advent of irrigation in the district. These figures show particularly the trend to greater content of potash and phosphate in surface soil from light through intermediate to heavy types. The heavy surface soil again is relatively poorly supplied with total lime.

The distribution of total nutrients with depth in the profile is illustrated also by the lower section of Table VII. As is usually the case with soils of the north, nitrogen and phosphate change but little, while potash, lime and magnesia show considerable variation with depth. Points of interest are the sharp change in potash with depth in the light soil, and the notable accumulation of lime and magnesia relatively close to the surface in the two heavier soils.

Availability of Phosphate and Potash.

The relations between "total" phosphate and potash and "available" nutrients in the same samples, as determined by solubility in 1 per cent. citric acid, are shown in Table VIII. for the three surface soils just discussed.

It is noted that, while considerable proportions of the total potash are in available form, the amounts of available phosphate are very low. The proportion of available to total potash is considerably lower in the heavy soil than for the two lighter types, but, as far as can be judged from determinations of this kind, all three groups show excellent potash conditions. Water-soluble potash determinations confirm this finding. In analyses for four soils recorded in a later section, two surface horizons show values corresponding to 7 and 14 parts of potash respectively per 100,000 of soil, while two subsoil horizons gave figures of 6 and 4 respectively on the same basis. The very poor phosphate situation is typical of northern soils in which low total reserves are rarely offset by any special degree of availability.

Table VIII.—Total and Available Nutrients.

Figures Parts per 100,000 *of Dry Soil.*

Soil Group.	Phosphoric Acid (P_2O_5).		Potash (K_2O).	
	Total.	Available.	Total.	Available.
Light ..	24	1	76	42
Intermediate ..	35	1	190	70
Heavy ..	46	2	319	67

Reaction (pH).

Determinations of reaction (pH) by quinhydrone or colourimetric methods are listed for all samples shown in the Appendix. These results are in line with those of Goulburn Valley soils. Values for the surface horizons are fairly variable, covering a range, pH 6·1 to 8·1, but deeper horizons are more uniform throughout the area, approximating to pH 8·4 at the depths at which lime accumulation manifests itself to appreciable degree (compare figures for "calcium carbonate in fine earth" in Appendix with pH values). Below these latter zones, reaction values are of the order pH 8·8. A considerable body of information on the reactions of these soils, other than those recorded in the Appendix, is in general agreement with the statements made above.

There is a tendency in these soils to give lower reaction values for the surface horizons in the heavy types than others. However, no definite segregation of the soil types on the basis of reaction may be made because of extensive variations within each type, due partly to varying use of lime, local concentrations of salt, &c. Variability within a small area of uniform soil type is illustrated by data from 25 bores distributed over

Table IX.—Replaceable Bases in Soils.

Sample Number.	Depth (inches).	Total Replaceable Bases (mg. Equivalents per 100 gm).	Percentages of Total Bases.			
			Calcium (Ca).	Magnesium (Mg).	Sodium (Na).	Potassium (K).
3993	56 to 84	30·8	30	46	21	3
3999	36 to 72	25·4	18	45	28	9
4040	45 to 53	40·5	23	45	28	4
4033	67 to 88	16·5	28	44	21	7
4024	8 to 28	20·2	40	41	13	6
4011	9 to 29	30·3	29	38	29	4

half an acre of Bamawm Extension Sandy Loam. Here surface horizons varied from pH 7·2 to 8·4 and deeper horizons over a smaller range, samples from the 5 feet to 6 feet zone, for example, lying between pH 8·6 and 9·0.

Fig. 4.—Cleaning a main drain at Bamawm.

Replaceable Bases.

Results of estimation of replaceable bases by the method of Hissink are given in Table IX. The analyses show that the soils of the area are dominantly of the magnesia-clay type, the proportion of replaceable magnesia being high and fairly uniform throughout. This and other features of the analyses are comparable with results of previous work on soils from neighbouring regions (1, 2, 7, 8).

The first four results in Table IX. are for representatives of the deep grey clay. It is observed that, after magnesium, calcium and sodium are of roughly equal order. This unattractive clay constitution, together with the high actual amounts of clay often present in these zones, accounts for the poor permeability of these clays to water. the last two analyses in the table are for red clay pans in heavy soils. Of these, the second is regarded as more typical of the pan structures of the heavy soils in general than the first. Clay constitution in this case is of similar character to that of the deep grey clays.

Soluble Salts.

The figures listed in the Appendix for total soluble salts, determined by conductometric methods, do not disclose any notably high results for these typical profiles, the highest being 0·135 per cent. for a surface sample of Ballendella Loam. In the majority of the heavier ("pan") soils in which the surface horizon has been subdivided in sampling, the surface samples show considerably greater total salt content than the sub-surface zone—note Bamawm Sandy Loam and Ballendella Loam. It is evident from the Appendix, that when total soluble salts are low, chloride expressed as sodium chloride usually is not dominant among the salts, but with higher amounts of total salts, chloride assumes greater relative importance. For "sodium chloride" values of approximately 30 parts per 100,000, a figure which was used as a standard for salt work during the survey, total soluble salts are of the order of 100 parts per 100,000.

More detailed analyses of certain samples show the contribution made by different constituents to the total soluble salts under different conditions. The upper group of results in Table X. shows anion analyses for six representative samples. The relative importance of bicarbonate in some of the samples with lower total salts, and the rises in both chloride and sulphate with increasing total salts are noted. Carbonate is absent from this group, as also from the other analyses recorded in the Table.

The second group of salt analyses is included to illustrate unusual effects which have occurred in different parts of the Bamawm area where definite salt accumulation has taken place in recent years. The samples concerned in this group were all taken from one profile of Bawawm Sandy Loam, representative of an area in which citrus was dying. There is a marked accumulation of salt above 4 feet, at which depth there is a sudden change in the salt situation. A profile from a similar adjoining area showed the same type of change at approximately 2 feet. This soil type is one of those subject to "interpenetration" of water, and, therefore, of salt, through the permeable subsoil. Probably an effect of this kind has taken place in this case. With regard to the actual analytical figures for this profile, the relatively low and almost uniform amount of bicarbonate throughout the profile is noted, together with the high figures for chloride and sulphate in the affected zones. The figures for lime and magnesia in these samples are such that high proportions of the anions must be in

combination with univalent radicles, probably sodium.

In view of the importance of relations between sodium and calcium in the soil solution, a further group of complete salt analyses was made on representative soils and subsoils. The importance of calcium lies in its action as a "protector" of soil structure, its effect on permeability and its specific effect in the nutrition of citrus. From these aspects, sodium is antagonistic, so that the relations between the two, expressed as chemical equivalents as in Table X., give the best guide to this feature of the soil economy. The results in the lowest section of Table X. show sharp differences between the surface soils and the subsoils in this respect. In both surface samples, lime is more than double the amount of soda, expressed in milli-equivalents. This is a fairly satisfactory relationship, but the situation in the subsoils, particularly the deeper one (3991), where lime is less than one-third of the amount of soda, is the reverse. This is typical of northern soils generally, where with increasing depth in the profile the tendency is for greater dominance of sodium in the clay sample and often in the soluble salts, in spite of the frequent presence of calcium carbonate. In Sample 3991 of Table X., for example, lime rubble was present in small amount in the field sample and calcium carbonate in the fine earth to the extent of 0·23 per cent. Other features of these analyses are the considerable proportions of potash, particularly in the surface, already commented upon in a previous section, the part played by magnesia, the dominance of bicarbonate and the relatively low order of the sulphate figures. The analysis for 4022 is remarkable in that the ordinary anions constitute but little more than one-third of the cations expressed as equivalents.

In general it may be stated that the relations between the soluble salts in soils of the Bamawm district are of similar nature to those in other northern districts, except that chloride plays a rather less dominant role and that sulphate is of rather more importance than usual, particularly in some of the areas where definite accumulation of salt has occurred.

Distribution of Soil Types.

The manner in which occurrence of the various soil types are scattered over the holdings investigated is shown in Maps 2 and 3. While there is no very obvious segregation of individual types towards particular parts of the area, extensive adjacent occurrences of sandy-surface types are

TABLE X.—SOLUBLE SALTS IN BAMAWM SOILS.

Figures are parts per 100,000.

No.	Type.	Depth.	Total Salts.	Chlorine (Cl).	Carbonate (CO_3).	Bicarbonate (HCO_3).	Sulphate (SO_4).	Sodium (Na).	Potash (K).	Lime (Ca).	Magnesium (Mg).
		Inches.									
4001	Bamawm Sand ..	9 to 22	10	3	Nil	2	2	..	..	..	..
4043	Bamawm Sandy Loam	0 to 5	40	5	,,	8	9	..	..	..	..
4016	Bamawm Fine Sandy Loam	6 to 12	45	3	,,	12	6	..	..	..	..
3988	Bamawm Extension Sandy Loam	11 to 13	50	13	,,	12	4	..	..	..	..
4013	Lockington Loam ..	38 to 78	55	2	,,	34	12	..	..	..	..
4034	Ballendella Sandy Loam	0 to 5	110	24	,,	16	17	..	..	..	..
	Bamawm Sandy Loam	0 to 6	678	210	,,	30	215	..	..	34	43
	,, ,, ,,	6 to 12	834	270	,,	33	217	..	..	60	35
	,, ,, ,,	12 to 24	704	180	,,	35	216	..	..	46	52
	,, ,, ,,	24 to 36	565	121	,,	35	203	..	..	41	64
	,, ,, ,,	36 to 48	505	95	,,	29	212	..	..	36	55
	,, ,, ,,	48 to 54	270	18	,,	24	116	..	..	27	52
	,, ,, ,,	54 to 60	..	16	..	..	..	..	..	..	..
	,, ,, ,,	60 to 72	..	16	..	..	..	..	..	..	..
	As milli-equivalents per 100 *gms. of soil (except total salts).*										
4022	Ballendella Loam ..	0 to 4	135	0·18	Nil	0·16	0·17	0·23	0·30	0·51	0·39
4000	Bamawm Sand ..	0 to 9	38	0·04	,,	0·43	0·08	0·11	0·15	0·27	0·17
4029	Bamawm Sandy Loam	12 to 21	55	0·09	,,	0·28	0·17	0·21	0·13	0·23	0·24
3991	Bamawm Extension Sandy Loam	24 to 34	58	0·23	,,	0·62	0·14	0·60	0·08	0·18	0·24

noted in certain areas, especially on the high land near channels. Effects of this kind are made evident in the maps by the use of stipples to denote sandy surface.

Detailed examination of the occurrences reveals certain other tendencies toward differential distribution over the area. Thus, while the occurrence of any particular soil type in any individual section of the area usually is of the order of 10 per cent. only of the total area surveyed in that section, occurrences to the extent of 28 per cent. on this basis are revealed for Bamawm Fine Sandy Loam in Section C, for Ballendella Sandy Loam in Section E, and for Bamawm Extension Sandy Loam in Bamawm Extension. Of rather lower order, down to 20 per cent. are occurrences of Ballendella Loam in Section A, Bamawm Loam in Section C, Bamawm Extension Sandy Loam in Section E, and Ballendella and Bamawm Loams in Section F. Bamawm Sandy Loam has its most extensive occurrence in Section B.

It has been noted previously that the two lightest types occur to the combined extent of 15 per cent. of the total area surveyed. Section A, with 36 per cent. of its citrus area, and Section B with 22 per cent., covered by these types are outstanding. The proportions in Section F are negligible, in Section C and Bamawm Extension only 7 and 9 per cent. respectively, while Section E has 13 per cent., mainly as Lockington Sand. Section A is remarkable in that it shows the highest percentage occurrences of the two heaviest types combined as well as of the two lightest types, so that it has the very low proportion of 24 per cent. of intermediate soils, compared with the 50 per cent. shown by the whole settlement. Section B approaches this position with 38 per cent. of intermediate types, the figures for the remaining sections being of the order 60 per cent.

Relation to Topography.—The maps show that there is great complexity in the distribution of soil types in this area, and apart from certain tendencies described above, the occurrences appear to be almost at random. It is not possible to associate the occurrence of particular types of soil with certain contour levels over the whole area, as has been done in some other districts of Victoria (7, 8). Nevertheless there is definite relation between distribution of soil types and contour, this being obscured when the area is considered as a whole, because of the general slope of the country.

These relations have been investigated by tracing the position of every bore made during the survey on large scale contour maps made by the Water Commission. By elimination of the effect of general slope in the area by use of "relative contours" for each local area examined, it has been shown that the light types virtually monopolize the higher levels, with the heavy types assuming similar dominance at lower levels. The intermediate group fulfils its characteristic function of linkage, occurring to some extent over the whole range of relative levels investigated, with typical occurrence on the intermediate slopes.

In this way it is demonstrated that local contour is a determining factor in soil type occurrence at Bamawm, light types tending to occupy the rises, with heavy soils on the flats and intermediate soils on the intervening slopes. It is noted here that the sandy-surfaced intermediate Types 3 and 5, and the corresponding heavy Type 7 show definite tendency to differentiation away from the remainder of their groups and association with the light soils on the higher land.

It follows from the above discussion that a distribution of soil type occurrences, which on the maps appears to be rather a chaotic scatter, is really an aggregation of ordered sequences.

Sequences of Soil Types.—This general progression from light, through intermediate to heavy soils in accordance with local topography tends to follow certain lines through related types. In describing this aspect, adjacent occurrences of different soil types will be called a "combination," and sets of such combinations a "sequence."

Types 1 and 2 tend to occur in combination, but, if they change to a type outside the light group, give place as a rule to Type 3, which changes usually to Type 5 or 7, retaining sandy surface. Similarly Type 4 combines typically with 6 or 8 and again 8 and 9 are associated frequently, the relatively heavy surface being retained in all these cases. These combinations illustrate sequence through types related by surface character: illustrative of retention of essential subsoil character when surface soil changes is the combination frequently found of Types 5 and 9. Certain sequences, summations of the combinations mentioned, are recognized as typical such as Types 1 or 2, 3, 5 or 7; 3, 5, 9, 8; 6, 8, 9, &c.

Combinations Showing Strong Contrast.—The difficulties associated with adjacent occurrences of contrasted soil types under irrigation are well known. Any combinations between types with permeable subsoil zones and those without (Types 5, 6, 9) must be regarded as unfavourable from this point of view. Thus Types 5 and 6 are "problem"

types in the sense that their presence on a holding is usually associated with trouble.

Certain of the wider contrasts, such as the infrequent combination, 1 with 9, and the much more common association 3 with 8, are obvious to the irrigator, but others may give little or no surface indication of change of soil type. Instances of the latter which occur fairly frequently are the combinations, 2 with 7, and 4 with 8. The same effect is involved in the more narrow contrast, 3 with 5, of quite frequent occurrence. Combinations such as these are much more likely to lead to difficulty than those of the class typified by that of 3 with 4, where contrast is not wide and is concerned largely with the surface soil, so that the existence of the change in soil type is usually known to the irrigator, who may adjust his handling of the soils accordingly.

Soil Types and Original Vegetation.—A matter of considerable interest is the possibility of relating the distribution of soil types as found in the survey with the occurrence of certain vegetation associations prior to clearing.

From information obtained from early settlers it would appear that, as might be expected, the light group of soils 1 and 2 is associated typically with Murray pine, while the remaining sandy-surface types 3, 5 and 7 carried pine, pine and yellow box, or yellow box in different parts of the area. The heavier-surfaced Types 4, 6, 8, and 9 are associated typically with the former occurrence of grey box.

Genesis of Soils and Relations between Types.

Pedo-genic Process.—From the manner in which description of individual soil types proceeded in an earlier section, it is evident that close relations exist between these Bamawm soil types. Obviously they have developed under the same type of soil-forming process, one which allows considerable mobility of clay in the profile. This process leads characteristically in this area to formation of clay-accumulation zones, with lighter surface horizons overlying them and lighter parent material below. This effect is elaborated in several types to very definite clay pan structure. The deep grey clay is considered to have played only a secondary part in the development of the upper soil, the parent material for the soil being discontinuous with this bed clay. The parent alluvium is characteristically of fine sandy to silty type, carrying mica and other constituents associating it with the Eastern Cordillera.

In three types, namely, Ballendella Loam, Bamawm Fine Sandy Loam, and Lockington Loam, the operation of exceptional circumstances has caused a profile structure differing essentially from those of the other types. In these soils there is no marked lightening of texture below the horizon of clay accumulation. This is attributed to the original parent material having been relatively heavy compared with other types and in addition the depth of this material overlying the grey bed-clay was relatively shallow. It appears likely that profile development proceeded in these soils in a manner essentially similar to that in the other types, but, largely because of the second factor mentioned, the original parent material as such has virtually disappeared from the profile, the position occupied by it in other types being taken by an intermingling of transition zones of clay accumulation below the main clay-pan and above the deep grey clay. In all these types, considerations of this kind are complicated by the possibility of lack of uniformity of the parent material with depth.

The type of soil-building process envisaged for these soils is that of solonization, that is, a process in which mobility of clay under leaching is engendered by a certain degree of saturation of the soil colloids with sodium. This implies a preliminary salinized condition of the soil. Although they occur in the regional zone of the Red Brown Earths and certain morphological features often associated with solonetz soils are not fully developed in these Bamawm soils, it is considered that their general properties place them among the solonized group of alkaline soils.

Operation of such a process will lead to development of various soil types depending on depth and nature of parent material, lime and soluble salt relations, and topographic and vegetation conditions in various parts of the area. The importance of lime and soluble salt lies in their effect on mobility of clay. The structural position in the profiles at which lime accumulation occurs has been noted already. It is likely that, prior to irrigation, the main accumulations of soluble salts in these soils were rather deeper in the profiles than the major lime zones. These constituents exert potent influence in development of profile under conditions such as those prevailing at Bamawm, because clay in process of being washed down the profile in dispersed condition is flocculated on approaching a zone in which lime and salts are accumulated. This action leads of course to clay accumulation in the zone of flocculation giving conditions favourable for " pan " formation.

On this basis, the heavier types, with less inherent facility for leaching, and greater content of lime and, as shown later, of soluble salt, tend

to more striking development and occurrence nearer the surface of clay pan features than the light soils. In this connexion, the relations between Types 1, 2, 3, and 7 are of considerable interest. In these types there is comparatively small difference in average texture when the whole profile is considered, as in Table XI., although a gradation in the series is evident. In spite of this general similarity, profile development has proceeded to give considerable differences in structure, especially as between Types 1 and 7. Type 2 is not far removed in heavier texture and shallowing of profile from Type 1, with its deep horizons and comparatively small tendency to clay accumulation. Type 3 carries the tendency shown by Type 2 to a further definite stage while in Type 7 a very definite clay-pan formation fairly close to the surface is shown. In the sense of the above discussion, these differences follow from the rather striking differences in relative importance of lime in the four types as indicated by Table VI. and the gradation in average profile texture.

Texture Gradient.—Quantitative expression is given to the texture range covered by the soil types of the area in Table XI. Two entries are shown, the first giving weighted average for clay content for each specimen profile listed in the Appendix, considered over the whole profile to the grey clay. The second shows clay content for the major zone of clay accumulation in each profile.

The gradation in average texture is evident in the upper entries in the Table, with Type 7 showing a striking break in the general trend, reflecting its affinities with the lighter soils, as discussed above. Similar trend is shown in the intensity of clay accumulation as given in the lower entries, the basis on which Type 7 was included in the heavy group being made clear in this case since it takes a normal position in general gradient.

For both entries it is noted that a range of the order of 30 per cent. of clay is covered between the lightest and heaviest types and that, with the exception mentioned, the types are distributed over this range in a manner consistent with their separation into light, intermediate, and heavy groups.

Wind Action in Profile Development.—There is little doubt that aeolian action has contributed, in notable extent, to the formation of some of these soils. The light group, the typical "pine ridge" soils, undoubtedly owe their depth and general character, in some considerable extent, to accession of wind-borne material. Lockington Sand, in view of its characteristic relations between the two sand fractions, would appear to have been specially subject to action of this kind.

In certain areas of the settlement there is evidence of wind erosion of some of the soils following at least partial profile development. In general, however, the possible extent of wind activity as a factor in the development of these soils is difficult to assess. In view of the tendency, noted in a previous section for sandy-surfaced types to occur in combination although subsoils may show considerable changes, it appears likely that deposition by wind of sandy material may have been important in modifying the surface texture of types such as Ballendella Sandy Loam.

Regimentation of the Soils of the Area.—The gradation of structural properties in the series of related Types 1, 2, 3, and 7 has been discussed. Linking the three groups of light, intermediate, and heavy soils as it does, this series may be regarded as a backbone for the soils of the district regarded as a body.

Associated with the four types mentioned, because of common possession of "parent" zones of relatively light texture, are Types 4 and 8. The loam to silty loam nature of the surface horizons of these two soils distinguishes them from the related Types 3 and 7 of the above series, and reflects some tendency to heavier character in the parent material. As indicated

TABLE XI.—CLAY RELATIONS IN THE SOIL TYPES.

(All clay figures have been adjusted to the basis sand + silt + clay = 100 per cent.).

—	Light.		Intermediate.				Heavy.		
Type Number.	1.	2.	3.	4.	5.	6.	7.	8.	9.
	%	%	%	%	%	%	%	%	%
Weighted average for profiles—Clay content	17·3	19·1	21·8	26·7	25·6	28·6	22·5	36·2	44·3
Major zone of clay Accumulation—Clay content ..	22·9	32·4	38·7	32·0	38·4	37·0	49·0	51·3	55·0

previously, this tendency, carried to the point of definite difference and associated with generally shallow profile, is responsible for the setting apart of the three other types of the area, numbers 5, 6, and 9, as a group differing essentially from the remainder in water relations, notably in permeability and drainage.

This presentation of the situation serves to illustrate the tendency in the soil of the area considered as a population, to continuous variation over a certain range of properties rather than to discontinuous variation involving segregation into types. This may be regarded as typical of broad alluvial occurrences of this kind with little topographic relief, but it emphasises the difficulties of soil classification under such conditions and lends point to the previous discussion on variations within individual types. At the same time, it is made manifest that the types selected to cover the range of variation found in these soils form a logical basis for practical assembly and utilization of the data obtained in the course of this survey.

Occurrence of Free Water.

There is no doubt that the running of a large unlined irrigation channel such as the Waranga–Mallee Main through a district of this kind has profound effect on the ground water level. To the north in the irrigation areas now in question, the position is complicated by the fall of the country in this direction and the presence of channel systems distributing from the Main and by the naturally potent factor of irrigation itself. The level of water in Bamawm wells is now approximately 16 feet, as compared with depths of about 80 feet prior to advent of irrigation.

The effect of general elevation of ground-water level is to augment the possibility of dangerously high water table being developed in any particular area due to unusual local conditions and/or to indiscriminate use of irrigation water. In the Bamawm soils, profile structure of many of the types is of such character, and distribution of occurrences of the various types so complex, that conditions of unusual difficulty exist in this district with regard to the use and control of water.

Extent and Distribution of Water-logged Areas.

During the survey, every bore was examined for presence of free water and, when present, its depth from the surface was recorded. In classifying the information obtained, an arbitrary level of 4 feet from the surface was adopted, so that occurrences of waterlogged soil zones within this limit were regarded as dangerous for citrus. A second class was made in which waterlogged zones occurred within the depths 4 to 6 feet, each being regarded as constituting incipient trouble. Of 93 blocks, 52 showed occurrences of the first kind, while a further 21, free from trouble of the more severe order, showed areas of the second class. The total areas involved for the citrus investigated are estimated at 137 acres dangerously affected and 97 in potential danger, corresponding to 15 per cent. and 11 per cent. respectively of the total citrus area.

Occurrences of soils showing free water within 4 feet of the surface are delineated on Maps 2 and 3. In many cases the areas affected are associated closely with irrigation channels. Several factors are involved here. As in all irrigation systems of this kind the channels must follow the high land which, as has been shown, is characteristically of light soil at Bamawm.

Under normal practice, irrigation of individual holdings proceeds from these channels over light soils on to the heavier types. Unless special precautions are taken the probability of over watering the light soil is high. Such effects, combined with channel influence, naturally expose irrigated land of any kind adjoining the channels to special risks from this point of view. Obviously the extent of the risk is dependent on a variety of factors, including channel structure, hydrodynamic gradient, nature of the soil adjoining the channel and its condition of uniformity or of diversification into types as well as its contour relations. As has been indicated, soil character and distribution in the Bamawm area is such that inherent disabilities from this point of view exist in many parts of the settlement.

Another rather disturbing feature of the distribution of waterlogged soils as shown on the maps is the proximity of several of the occurrences to community drainage structures. In several of these cases the indication is that the zone of effective influence of the drain is relatively narrow. These outfall drains of course follow the low levels, so that the soil adjoining them is typically heavy. On this account drainage rate from these soils may be expected to be rather restricted.

Nature of Waterlogging in Affected Zones.

Extensive development of troubles due to free water in the Bamawm area is due in part to the character of the "deep grey clay," the bedding material for the district. This is so slowly permeable to water that it may be regarded from the

practical standpoint as being impermeable. The fact that the general ground-water level has been elevated to considerable degree since advent of irrigation, shows that water penetrates this barrier in time, but this is hardly likely to have occurred by permeation of the mass of the clay. It is suggested that it has occurred by a process of inter-penetration of water, that is, percolation down pipes and seams of more amenable material included in the general clay body. Actually a process of similar nature occurs fairly generally even in the wetting of surface soils of heavy character by rainfall, where penetration occurs to considerable extent down structural cracks.

Perched Water Tables.—The grey clay, then, is practically impervious. On this account most of the waterlogged zones in the Bamawm soils are due to water "perched" above this clay. In many cases this free water persists in the zones affected for such long periods that it is virtually permanent. It may be deduced from their general profile structure that most of the Bamawm soils are specially likely to show free water in the zones just above the bed-clay.

Several of the soil types show light "parent" material in this position underlying horizons of clay accumulation. The capacity of this light material for imbibing water is very much less than that of overlying zones, so that if water is applied to the soil to any notable degree in excess of the requirements of those portions of the profile overlying it, development of free water in the zone in question is almost certain. Such free water being held up at the surface of the deep grey clay, lateral drainage within the light zone along the surface of the grey clay offers the only means inherent in the profile structure for ready disposal of excess water. If such disposal is denied by any circumstance, the "parent" zone suffers the singularly unfortunate fate of being trapped in a watery "grave" between its time-honoured bed and its own progeny. Attention will be given later to circumstances which may prevent such lateral drainage. Even if, as in the more favoured cases, such free water does not persist for years, it is likely to be present at least for temporary periods during the irrigation season, in the aggregate sufficiently prolonged to cause serious damage to citrus roots in the zones concerned.

True Water Tables.—In cases of these "perched" tables, continued boring of course reaches relatively dry clay, so that in many cases the impeding grey clay itself may be waterlogged for only a few inches in depth. In other cases, however, it appeared that the true ground-water had been reached, deep boring showing no essential change in the condition of the soil with respect to excess water. Such cases of elevation of the "true" water table to zones near the surface are logical developments from continued exposure to conditions of perched water table, leading in time to linking with the ground water. Several cases of waterlogging in light soils adjacent to channels appeared to be of this "generally waterlogged" kind, together with a number of instances on heavier land outside the citrus areas, where free water was found at about 3 feet from the surface during dry summer on areas that had not been irrigated for several years.

Shallow Water Tables of Persistent Character.—Both in true and perched water tables it is not implied that free water was found only within or below the "parent" material zone or the horizon corresponding to it. The above discussion indicates the manner in which such effects may develop; obviously their intensity may cover a wide range. Over developed, free water of either kind is subject to the possibility of continued elevation according to the extent of further access of water. At Bamawm some occurrences of free water were found within a few inches of the surface. Fortunately, the more general case in the area is that in which waterlogging, evident in the "parent" zone, did not extend to marked degree into the horizons above it. The depth of profile to the deep grey clay is thus a most important determining factor in this matter and the effects of interaction between this factor and that of root-penetration of citrus, an index to which is provided by its age, are seen clearly in a number of groves at Bamawm.

Shallow Waterlogging of Temporary Nature.—There is another type of waterlogging in Bamawm soils to which reference has been made already. This is essentially of temporary character, associated with the delayed penetration of water through the claypan structures characteristic of the profiles of several of the types. This effect may be detected in the field by examination soon after irrigation. The evidence, as described in a former section, of structural features in the zone immediately above the clay pan, indicates that the condition of temporary waterlogging, as an aggregate of repeated occurrence due to rainfall and irrigation, is of duration sufficient to produce significant change in the soil and therefore, presumably, likely adversely to affect citrus root-function.

When carried to its extreme, as in certain badly-graded or very flat occurrences of shallow heavy soil, notably Lockington Loam, this effect is synonymous with surface waterlogging, with its attendant dangers in collar-rot, &c. Figure 5 illustrates decline of citrus under such conditions.

Fig. 5.—A 20-year-old orange tree on Lockington Loam in advanced stage of decline due to root rot. No elevation of water table and no salt accumulation have occurred at this location. Adjacent inter-plants of pears.

Local Intensification of Waterlogging.—Where an area of soil with generally heavy subsoil character breaks in small patches into occurrences of light subsoil, the latter zones obviously will be the first to show waterlogging effects. Again, if the contour of the deep grey clay changes sharply to give "cup" structures elevated above the general level of the bed-clay, similar effects obtain. Certain cases of death of individual or small numbers of citrus trees at Bamawm have been attributed after investigation to factors of this kind.

Incidence on Individual Soil Types.

The susceptibility of each soil type to occurrence of waterlogged zones in each of the two depth-zones mentioned above is shown in Table XII.

It is noted that the soil types fall into three classes with respect to susceptibility to free water in the upper zone. The two lightest types, especially Lockington Sand, show to very marked advantage, while the two types at the other extreme of texture are revealed as moderately susceptible. The five intervening types, being affected to the order of 20 per cent. must be regarded as specially liable to this trouble. Of these Ballendella Sandy Loam appears worst, with Bamawm Extension Sandy Loam but little better.

In occurrences of waterlogged soil within the zone 4 feet to 6 feet, the situation as shown by Table XII. is very different. Again three broad classes of soils are noted, the first including the four lightest types and being the most liable to free water at this depth. The four heavier types are bracketed together as of moderate susceptibility, while the heaviest type stands alone as virtually unaffected.

Using summations of the two figures for each type to give a general index to incidence of water-logging on individual types, the values set out in the lowest entry in Table XII. group the two lightest and the two heaviest soils together as being definitely less susceptible as a class than the five intervening types. In the first class the heaviest type, Lockington Loam, is noted as least susceptible, while in the second class a definite trend is evident in the figures from lighter to heavier types, the lightest of these, Bamawm Extension Sandy Loam showing the gravely high figure of 36 per cent. of its total area affected by free water as judged on this criterion.

The relations between proportions affected by free water at one or other of the two depth-zones in each soil type are of considerable interest. It follows from Table XII. and the above discussion that these relations definitely change character from light to heavy soils. Types 1 and 2 showed marked preponderance of affection in the lower zone, while in Types 3 and 4 the situation is reversed, with relations between the two zones not

Table XII.—Incidence of Waterlogging on Individual Soil Types.

(*Figures show area affected in each Type as percentage of Total Area of the Type Examined.*)

——	Lockington Sand. (Type 1.)	Bamawm Sand. (Type 2.)	Bamawm Extension Sandy Loam. (Type 3.)	Bamawm Loam. (Type 4.)	Ballendella Sandy Loam. (Type 5.)	Bamawm Fine Sandy Loam. (Type 6.)	Bamawm Sandy Loam. (Type 7.)	Ballendella Loam. (Type 8.)	Lockington Loam. (Type 9.)
0 to 4 feet	3	7	20	17	22	18	17	12	12
4 feet to 6 feet	15	14	16	15	6	11	8	8	1
0 to 6 feet	18	21	36	32	28	29	25	20	13

far from equality. Types 5 to 8 show marked dominance in the upper zone, a condition specially notable in Type 5. This is carried to its logical extreme in the heaviest Type 9, where free water in the lower zone is negligible.

Reference to the earlier discussion on nature of waterlogging in affected areas in its emphasis of the importance of depth of profile to the grey clay, serves to elucidate the situation just described. Most of the free water occurrences being perched above this grey clay, obviously their likelihood of occurrence within the 0 to 4 feet or 4 feet to 6 feet zones depends, as far as influence of soil type is concerned, on the depth from the surface at which this clay-bed begins. As shown previously, this depth tends to be more shallow with increasing general heaviness of profile.

Fig. 6.—Seepage effects at a soil type junction (indicated by ×) adjoining irrigated pastures

Seepage.—It has been indicated above that, as a general principle for the soils investigated, lateral drainage along the surface of the deep grey clay is the only natural facility available for removal of excess water from subsoil zones at an appreciable rate. In this report use of the term "seepage" will be confined to movement of free water in a direction predominantly lateral. Evidences of such movement are widespread at Bamawm.

Certain of the more favoured citrus areas are still naturally drained in this way, often at the expense of areas lying at lower levels. More generally, however, opportunities for such internal drainage, which may have existed formerly, are no longer available to sufficient extent because the areas which formerly carried the seepage water to an outfall are themselves waterlogged, i.e., access of water to them by irrigation water applied and by seepage, is greater than can be handled by their disposal facilities. In this way, the cumulative nature of the problem from the community standpoint becomes evident.

The effect just described is one of the circumstances mentioned formerly, which may prevent disposal of excess water from any particular area by lateral movement, and thus lead to elevation of water table in that area. Changes in subsoil character are of obvious importance in this connexion. Where types with permeable subsoils abut on occurrences of types with heavier subsoil horizons in areas subject to seepage, it is evident that when the water gradient is from the first to the second, trouble is very likely to supervene near the junction of soil types. Rate of penetration into the heavy subsoil being slow, seepage water tends to accumulate at the junction and to rise there. Figure 6 illustrates such a case, in which seepage from the pasture shown in the foreground, which is on light soil, meets a soil type change of this character, at the point indicated. The effect on tree condition is obvious. These troubles showed first in the lighter soil type within the grove, to the right of the photograph, at a point near the soil-type boundary. The trees first effected have since died. Such effects normally show first in the lighter type; but may extend later into both soil types. The situation as to which combinations of soil types are likely to give trouble is covered by an earlier section on "combinations showing strong contrast" and by the above discussion on incidence of free-water occurrence on individual types of soil.

In this connexion the contrast between proportions of areas affected at 4 feet to 6 feet in the two heaviest types is illuminating. These types are comparable in the two upper horizons, and therefore irrigation effects are comparable. It is difficult to get them to take water and the penetration of that water which reaches the red clay pan is delayed. Ballendella Loam however has a "parent" zone of considerably lighter texture than the corresponding horizon in Lockington Loam. Moreover, the former type is associated often with much lighter soils such as Bamawm

Extension Sandy Loam. It is, therefore, liable to inter-penetration of seepage water through the parent zone. To this is attributed the contrast noted between this type and Lockington Loam. Unfortunately, the presence of several occurrences of Ballendella Loam in waterlogged condition adjacent to main drains suggests that, once waterlogged, this soil does not show ready response to drainage installation.

Special Consideration of Intermediate Soils.

It was demonstrated above that the intermediate soils are specially susceptible to development of waterlogging. This is due to their general character as linkage soils, in the senses both of profile character and of contour relations. They occur typically on the intermediate slopes where they carry underdrainage from light types at higher levels as well as their own. Naturally, free water trouble is very likely to supervene where occurrences of these soils adjoin the heavy types, or where they diversify themselves into types with heavy subsoil (Ballendella Sandy Loam and Bamawm Fine Sandy Loam), and those without. Table XII. shows that the two types mentioned are comparable with the lighter-subsoil intermediate types in general susceptibility to waterlogging except in the relations between the two depth zones. It is evident, therefore, that free water gets into these types, by combination of seepage and irrigation, but prospects of removal of excess water are not bright because of their character.

With regard to the influence of intermediate soils generally on waterlogging, it is noted that Sections A and B, with 24 and 38 per cent. respectively of their citrus acreage covered by intermediate soils, show least proportions of their citrus areas affected, while Section C, with a corresponding figure of 64 per cent. is proportionately the most affected.

General Situation with Respect to Free Water.

The proportion of soils affected by waterlogging to some extent in the Bamawm citrus area is gravely high. It is noted here that in addition to areas already mentioned as having free water within 6 feet of the surface, a considerable area shows waterlogged soil at depths not much greater than this arbitrary level.

The situation for citrus cannot be considered separately from that of the other crops. The citrus area is very scattered, and individual plantings frequently are associated with crops requiring frequent irrigation, notably pasture. Such associations place the citrus under special disadvantage in an area of this kind, prone to seepage, where community irrigation has been practised with application of water, excessive with respect to the capacities of the soils. Combination of all the circumstances discussed above has resulted in the development of a water problem which dominates the situation in the district as far as citrus is concerned. As in most northern regions, effects due to soil salinity are attendant upon those caused by excess water.

Soil Salinity.

During the survey, analyses were made of samples from some 500 bores to show sodium chloride content as an average for the upper 3 feet of soil. In many cases further information was obtained for the zones 3 feet to 6 feet. In classifying this information, an arbitrary limit of 30 parts of sodium chloride per 100,000 of soil for the upper 3 feet has been adopted as that above which there exists the possibility of danger to citrus. This figure is based on previous experience in Victoria (3, 4) and on the fact, demonstrated in a previous section, that sodium chloride plays a rather less dominant role among total soluble salts in the Bamawm area than in certain other Victorian settlements. As the figures for sodium chloride at present in question are utilized as an index to general soil salinity, it was considered that the danger level for citrus in this area should not be set above the value stated.

Maps 2 and 3 show the distribution of areas with salt content above this standard, while the general position with respect to salt content of soils, for the holdings investigated, is shown in Table XIII. Of 93 blocks examined, 56 showed some areas above this salt criterion.

Table XIII.—Distribution of Sodium Chloride Content in Bamawm Soils.

(*Figures represent percentages of the total bores which fell into each salt range.*)

Salt Content as Parts per 100,000 of Dry Soil.	Less than 20.	21 to 30.	31 to 40.	41 to 50.	51 to 75.	76 to 100.	101 to 200.	More than 200.
Depth—								
0 to 3 feet ..	55	14	5	7	8	6	3	1
3 feet to 6 feet ..	57	16	7	5	7	2	5	2

It is of interest to compare the range of salt figures shown in Table XIII. with that in other districts subject to salinity. Figures on the same basis for 0 to 3 feet are available for the settlements of Tresco West and Kangaroo Lake Estate (8). These Bamawm soils compare very favourably with those of the settlements mentioned, showing 69 per cent. of the bores below 30 "parts" of salt, compared with 47 per cent. for Tresco West and 52 per cent. for Kangaroo Lake Estate. For the range below 20 "parts," the corresponding figures are 55, 34 and 24 per cent.

The Table shows that in the Bamawm soils the distribution of salt results for 3 feet to 6 feet is very similar to that in the upper 3 feet of soil.

Susceptibility of Individual Soil Types to Salinity.

In Table XIV. two comparisons between the various soil types with respect to salinity in the upper 3 feet are made. In the first a general indication of susceptibility to values above 30 parts of salt per 100,000 of soil is given, while in the second consideration is restricted to holdings showing this concentration of salt at one point at least, such being described for the present purpose as "salt-affected" blocks. The second system possibly gives a better indication of susceptibility, since it excludes areas showing little inherent tendency to salinity. It brings Bamawm Sandy Loam into line with the other heavy types and rather alters the relative standing of Bamawm Sand.

The Table shows obvious relation between general texture and salinity. The light types definitely stand apart in their relative freedom from affection, Lockington Sand being outstanding. "Affected" soils in this sense mean those bores showing values over the salt standard named, independent of the condition of the citrus carried. Among the remaining types, 3, 5, and also 7 on the wider system of comparison are on a much lower level of susceptibility than Types 4, 6, 8 and 9. The three types mentioned are all sandy-surfaced, so that their favourable character in connexion with salinity may be attributed to specially favourable relations between total water incident on their surfaces and the proportion available for leaching, an effect used also in connexion with their calcium carbonate relations to explain differences from the heavier-surfaced types. Table XIV. brings out in a striking manner the contrasts between the related pairs of soil Types 3 and 4, and also 5 and 6 from this aspect.

Special Standing of Intermediate Soils.

While Lockington Loam, the heaviest soil type, stands definitely as the type most likely to show "affected" occurrence, examination of the salt data shows that the intermediate soils, as in the case of waterlogging, occupy a special position. Thus for the heavy type in general, although salt values often may exceed the standard of 30, they seldom go higher than 100 parts of sodium chloride per 100,000 of soil in the upper 3 feet. In the intermediate soils, while the general condition of affection occurs rather less frequently, the scatter of salt figures is much wider. Most of the very high salt results recorded for this district, as in Table XIII. and in other work, have been found in this group of soils. Thus Ballendella Loam, outstanding among the lighter soils in general salinity as shown in Table XIV., shows wide range in salt figures extending to high values, while for Bamawm Fine Sandy Loam some very high figures are recorded.

The evidence available goes to show that inherent soil salinity is correlated with general texture of the profile, but that the intermediate soils have proved most susceptible to access of salt, often to considerable extent, under conditions favouring redistribution of salt among the soils of individual areas under the influence of irrigation.

Process of Salt Accumulation.

Redistribution of salt occurs as the result of seepage and free water effects generally. In the

Table XIV.—Percentages of Bores of Each Type showing Sodium Chloride Content greater than 30 parts per 100,000 of Soil 0 to 3 feet:

Soil, Type, Name.	Lockington Sand. (Type 1.)	Bamawm Sand. (Type 2.)	Bamawm Extension Sandy Loam. (Type 3.)	Bamawm Loam. (Type 4.)	Ballendella Sandy Loam. (Type 5.)	Bamawm Fine Sandy Loam. (Type 6.)	Bamawm Sandy Loam. (Type 7.)	Ballendella Loam. (Type 8.)	Lockington Loam. (Type 9.)
When all holdings are considered	3	7	21	46	29	45	29	39	57
When "salt-affected blocks" only are considered ..	4	16	29	63	32	52	50	53	72

earlier stages at least of seepage action, the tendency is to leach salt from the lighter, higher land, and concentrate it where conditions favour such effects on the lower slopes among certain of the intermediate and heavy soils, already inherently more saline than the lighter soils. As an example of conditions attributed to this cause, adjacent occurrences of Lockington Sand and Bamawm Fine Sandy Loam on one block show salt figures for the upper 3 feet of 12 and 288 respectively. Both soils now show free water within 4 feet of the surface. Again under conditions of seepage towards the heavier soil an area of Bamawm Loam on another holding shows salt value of 38 parts compared with 279 in an adjoining occurrence of Ballendella Loam.

Already reference to the effect of topography has been made, its effect naturally being similar for salinity and free water, since salt is translocated by water. Examination of the salt information on the basis of "relative contours" shows that the light types are "salted" only when they occur at relatively low level, while in the intermediate and heavy types, affected soils occur over the whole contour range covered by these types, except that the highest levels in each case are not affected. Thus there is general relation between contour and liability to salt concentration.

Effect of Combination of Soil Types.

Certain combinations of soil types are unfavorable from the salt aspect, largely for the same reasons as for waterlogging. Cases illustrating two such combinations have been quoted above. Others of frequent occurrence are Bamawm Extension Sandy Loam with either Ballendella Loam or Bamawm Fine Sandy Loam, and of the latter with Lockington Loam. Although heavy types occur frequently in combination with each other, such combination is not often found on "salted" blocks, which show, typically, combinations between intermediate and heavy types. The types with heavy subsoil, viz., Ballendella Sandy Loam and Bamawm Fine Sandy Loam in particular, and also Lockington Loam, are indicative of salt trouble to the extent that groves on which they occur to any degree are already free from this problem, unless associated soils are of the heavier types. Thus where a grove consists almost entirely of Lockington Loam for example, salt trouble is not likely to supervene. In accordance with the foregoing discussion, it is found that, in general, in combinations of soil types in salt-affected areas, the higher salt values occur in the heavier soils. Certain notable exceptions occur, associated with development of high water table in the lighter soil, without corresponding development in the heavy type.

Variations of Salt Content with Depth.

The figures for content of sodium chloride in the Appendix do not show any consistent relation between salt concentration and depth. This applies also to the considerable amount of data available on this point from many examinations during the past decade. In some bores, surface concentration is demonstrated, in others the higher values occur at depth. The relation of excess water to these effects will be discussed later.

Table XV. shows the averaged results of a number of depth-distribution examinations in 1-foot sections, spread over a number of soil types in typical areas during the present survey.

Table XV.—Averaged Results for Sodium Chloride Content at Different Depths in Bamawm Soils.

Soil Zone (feet).	0 to 1.	1 to 2.	2 to 3.	3 to 4.	4 to 5.	5 to 6.
Sodium chloride content parts per 100,000 dry soil	23	39	36	40	41	43

It is noted that there is no marked segregation of salt at any particular depth, although the surface foot is definitely lower in salt content than succeeding zones. On the whole, these figures illustrate the general tendency in soils of this kind to show increasing salt content with depth. This tendency is more marked in some of the heavier soils which contributed to the average shown in the Table than in lighter types.

Similar conclusions are reached from the averaged results for salt content of all bores at 0 to 3 feet and 3 feet to 6 feet, as used for Table XIII. These averages are 31·6 and 35·0 respectively, and, as stated previously, the scatter of values at both depths is closely similar. It would appear therefore that, for the citrus soils of the area as a whole, there is at present fairly uniform distribution of salt in the profile. This situation is modified where conditions have favoured special accumulation of salt and also where water tables are unduly high.

It is likely that salt conditions prior to irrigation were quite different from those just described. From the method of profile development of these Bamawm soils, it is almost certain that salt tended

to concentrate in these soils in the "parent material" position. The original profiles, therefore, would show notable increase of salt concentration in the lower depths. Confirmation of this deduction from their profile structure is given by a series of profile samples taken from this district in 1910 prior to advent of irrigation. On the information available it is possible to classify these profiles only into two broad groups of lighter and heavier soils. The difference between the two sets as listed in Table XVI. is very striking. Not only do these figures confirm the general relation between texture and inherent salinity pointed out above, but also they demonstrate very forcibly the difference in depth-distribution between light and heavier types.

TABLE XVI.—DISTRIBUTION OF SODIUM CHLORIDE IN BAMAWM SOILS PRIOR TO IRRIGATION.

(*Figures show Sodium Chloride as Parts per* 100,000 *of Dry Soil*).

—	Light Types (Average of 5 Profiles).	Heavier Types. (Average of 7 Profiles).
Surface soil	5	15
Subsoil	8	42
Deeper subsoil ..	18	180

HIGH CONCENTRATIONS OF SALT.

As in most districts subject to salinity, certain combinations of local circumstances, some of which have been discussed, may lead to excessive salt accumulation in certain areas. Two cases were quoted above. Under Bamawm conditions the trouble usually develops gradually in any particular area, so that in the earlier stages there is often high degree of salt variability from point to point in the area in question, a variation reflected in the condition of the trees. Later with increasing general impregnation, this variability is smoothed to a degree, usually at such a general level that citriculture is no longer feasible.

It is recorded here that the highest figure for sodium chloride content found in Bamawm soils is approximately 4 per cent. for a surface sample of Bamawm Loam. For sustained salt content are cited certain profiles showing sodium chloride content of the order of 0·6 per cent. for the upper 4 feet. In such an area, depth-distribution of salt may vary considerably from bore to bore and particularly from season to season. Rainfall or prolonged dry weather may alter conditions in land no longer irrigated; watering and fluctuations of water-table affect the distribution in irrigated land. Typical of surface concentration under strong impregnation with salt and cessation of irrigation are figures of 1485 and 138 parts of sodium chloride per 100,000 of soil for the surface 6 inches and the 6 inches to 12 inches zones respectively in an area of Bamawm Loam. The second group of analyses in Table X. shows marked concentration above 4 feet, under conditions of irrigation. An example of salt concentration at depth in a saline area under irrigation is shown by the sodium chloride figures 20, 33, 528 parts per 100,000 for successive 1-foot depths from the surface. In this case free water occurred at a depth of approximately 2 feet.

Relations between Salt and Excess Water.

Certain aspects of the relations between excess water and salt translocation and concentration have been mentioned. Usually, salt effects go in train with those of free water. For instance, Ballendella Loam, at the point indicated in Fig. 6, used to illustrate free water effect, contained 71 parts of sodium chloride per 100,000 of soil in the upper 3 feet.

Concentration of salt within the root zones of citrus under influence of free water is due usually to elevation of water-table, whether true or perched. To such elevation, excess water applied to the surface by irrigation and extraneous water inter-penetrated into the soil by seepage may contribute in varying proportion. In any case, the likelihood exists of concentration of salt, whether or not the water table has risen through the deep grey clay or developed above it by perching. If the latter, salt in the "parent" zone position in the profile, which was shown formerly to be the most likely horizon for salt accumulation during the process of profile building, is carried upward with the rising water. If the former, salt inherent in the deep grey clay adds its effect to that just mentioned. The special significance of any contribution made by seepage lies in the fact that its movement occurs typically through the "parent" material, inherently tending to salinity, so that in lateral penetration through this zone it may be expected to carry with it into the area of waterlogging considerable amounts of salt extraneous to that area. Local conditions, including contour relations and changes of soil type, which are conducive to development of such areas of waterlogging have been described, the special position of the intermediate soils being emphasized with regard to both waterlogging and salinity.

Fig. 7.—Trees in excellent condition at 23 years on Bamawm Sand.

When water-table is elevated to the root zone, or to a level at which "capillary fringe" effects involving both water and salt may extend from the water-table into the root zone, it is evident that conditions favour accumulation of damaging concentration of salt. With the exception of certain heavy soils, salt values greater than about 50 to 60 parts of sodium chloride per 100,000 of soil in the upper 3 feet of these Bamawm soils generally may be attributed to action of this kind.

In several of the younger groves there have been indications of a water and salt problem before more than a small proportion of trees have shown injury. "Black" or "salt" patches may appear in the grove, these being irregular spots and streaks of very variable size showing on the soil surface. In typical cases, free water-table is found within 4 feet of the surface. Capillary rise in local areas of favorable soil structure gives the characteristic patchy distribution and tends to keep the soil moist in these areas, giving "black" appearance compared with the surrounding dry red-brown soil. Change in the humus contributes to this effect in some cases, although carbonate, usually associated with such change, has not been found in soluble salts in this area. Further development of this water and salt situation, and also of the root systems of the trees of course intensifies the problem and leads to corresponding degradation of the citrus.

Detailed study of the survey data concerning distribution of salt at different depths in the soil and the occurrence of elevated water-table shows that there are certain general relations between these factors, as might be expected on the basis of the above discussion. There is a tendency to salt concentration in the upper 3 feet rather than in the 3 feet to 6 feet zone where free water occurs within 4 feet of the surface. When the latter lies below 6 feet, the reverse tendency is shown, while for free water occurrences between 4 feet and 6 feet there is no appreciable segregation of salt toward either of the depth-zones mentioned.

Condition of Citrus in the Area.

General Condition.—In a majority of the Bamawm groves, stunted growth of the trees is a striking feature. Poor colour, with tendency to chlorosis, is also widespread and there is evidence of a general low level of nutrition. Examination, by Mr. Provan, revealed that annual growth increments for the citrus in the area are small in general, and, in many cases, few in actual number per tree. There are, of course, several excellent groves, and many showing splendid condition in certain portions. As in many other settlements, a notable feature is the generally good appearance of young trees. Over the whole area, however, there is an unduly high proportion of misses and unthrifty trees.

The general impression following survey of the entire citrus area of the district is that of extreme variation in tree health, giving a patchy effect both to the settlement as a whole and usually also to individual holdings. The condition of citrus in relation to certain factors is discussed below. In nearly all cases of unthrifty condition, the state of the trees is attributable, of course, to a complex of factors, but, as far as is practicable, the incidence of each individual factor in the Bamawm area is considered separately.

Excess Water.—Free water effect is regarded as the major factor determining the health of citrus in this area, both in its own right and by reason of its influence on the salt situation. The susceptibility of citrus to damage under prolonged wet conditions is well known; root respiration is inhibited, leading to generally impaired root function and predisposition to attack by root-rot organisms.

Many opportunities have been taken, in the course of this work, of examining root systems of unthrifty trees which have been grubbed out. In a majority of cases extensive lesions due to

root-rot were found, with particular damage in the lower root zones. Many such trees were on areas found to be waterlogged, but a fair proportion were in locations showing at the time of survey no free water at sufficient elevation to constitute danger. These latter, however, were usually on heavy soil with definite clay-pan character and may be attributed to the effect, mentioned in a previous section, of repeated temporary waterlogging above the pan. In such cases the effect of free water in this zone is intensified by the tendency to shallow rooting induced by the presence of the clay-pan.

In general, the condition of citrus in areas affected by free water reflects the intensity of development of free water, variations in which have been described. An exception has been mentioned, in that young groves may persist to the age of eight to ten years in good condition in spite of the presence of free water within 4 feet of the surface. This situation occurs in several cases where the area is not inherently saline to any notable degree. Even in the absence of further elevation of water-table, however, deeper root penetration with advancing age seals the fate of many trees, so that unthriftiness, first patchy and then more general, develops in typical cases.

Fig. 9.—Trees on Bamawm Sandy Loam, about 2½ chains from the location shown in Fig. 8, with free water 4 ft. 6 inches from the surface and sodium chloride content of 83 parts per 100,000 for the upper 3 feet of soil.

When modification of local factors has led to elevation of water-table under groves of mature trees, onset of citrus decline is often rapid. This again is related to the question of root penetration. A case is recorded of persistence of portion of a grove on Bamawm Extension Sandy Loam to the age of about 20 years in an area subject to seepage to the extent that very little irrigation water has been applied to this portion for fourteen years. Apparently the seepage zone was at sub-critical depth for some time, but at the time of survey stood slightly within 4 feet of the surface. These trees now are generally unthrifty, but it is unlikely that they would have developed to their present size under the conditions had not the area, as shown by survey data, been relatively free from salinity.

Salt Concentration.—In many investigations of citrus tree health in particular areas at Bamawm during the past two years or so, thrift has been correlated with salt content of the soil. Death has ensued in many cases where salt figures for the surface 3 feet exceeded 100 parts of sodium chloride per 100,000 of soil. In certain cases confirmation of salt injury as the major cause of decline has been obtained by the finding of high salt content in citrus leaves (c.f. (3)).

Fig. 8.—A contrast in tree growth reflecting change in soil type, water and salt conditions. Trees on Bamawm Extension Sandy Loam, with no free water within 6 feet of the surface. Compare Fig. 9.

While its arbitrary character must be recognized the standard of 30 parts of sodium chloride per 100,000 of soil in the upper 3 feet, as adopted for these soils, has proved of considerable value. With an average figure of this magnitude there are possibilities of segregation of sufficient quantities of total salts to certain parts of the root zone to cause definite injury to citrus. Examples of this have been noted at Bamawm. Even if, under the more favorable conditions, salt values of this order are not critical in character, indications to the blockholder of areas affected to this extent are valuable in that he is made aware of a situation which may develop to critical dimensions. When values of the order 50 to 60 parts are shown, the chances of injury to citrus in this area are fairly high c.f. (4), except for certain cases of young trees and others of heavy soils. In these cases the factors of root penetration and tendency to salt accumulation below the uppermost horizons are involved, so that conditions over a depth of 3 feet do not reflect adequately the situation in the major root zone.

Nutrition.—The condition of many trees of the settlement suggested poor nitrogen supply. While total nitrogen figures as set out in a previous section are not unduly low, there appears to be pronounced deficiency of available nitrogen in many areas. On a considerable proportion of holdings applications of readily available nitrogenous fertilizer are too meagre, and insufficient attention is given to green manuring. In certain cases where the latter point is not neglected, the value of the practice is reduced notably by the use of non-leguminous crops and/or by late sowing. There is need in many instances for institution of a definite policy of green manuring with crops such as tick-beans sown with adequate quantities of superphosphate.

Because of the influence of these factors it is difficult to determine to what extent the low level of nutrition prevailing on many of the holdings has contributed to general unthriftiness. In certain cases however investigation indicated poor nutrition, particularly from the nitrogen aspect, as the major factor determining the observed unsatisfactory condition of the citrus.

Occurrences of "mottle leaf" chlorosis in the district, which are of comparatively small extent, have been investigated during past years. They appeared to be due to deficiency of a minor element, but trials with various applications had little success until the more recent use of zinc salts, which appears to hold promise under these conditions.

Disease.—The widespread influence of root-rot fungi on citrus condition at Bamawm, particularly in association with waterlogging, has been mentioned. Nematode has been found associated with root systems in this district, but the significance of its occurrence with regard to tree health is not susceptible of dissociation from other factors, such as wet conditions.

Collar rot and bark blotch occur frequently at Bamawm. Subjection of such conditions to treatment by recognized methods is not as widely practised as is desirable. Certain growers have adopted the precaution of systematic inspection to reveal such troubles in their early stages, in view of the concealing of their effects by lower branches of the trees. In many cases their presence has not been suspected until obvious symptoms have supervened in the trees and prompted investigation. The effect of weeds in keeping the base of the trunk wet appears to have induced collar rot in certain trees even on light soils.

At the time of survey, red scale infestation was very prevalent. The effect of this parasite on the general condition of citrus is well known. Rigorous measures insisted upon by the Horticultural Division of the Department of Agriculture have led to considerable improvement in the district from this point of view. The Biological Branch has instituted trials of oil sprays against

Fig. 10.—Fourteen-year-old trees on Ballendella Loam illustrating poor colour and lack of vigour due to deficiency of available nitrogen.

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red scale at Bamawm. Black spot and other disease conditions contribute their effect on tree and fruit to the collection of factors impairing citriculture in the district.

Influence of Soil Type.—It is difficult to evaluate the influence of soil type as such on the condition of citrus in this area, because of the relations between soil type and incidence of free water and salinity. The difficulties of cultivation and of delayed penetration of water associated with growth of citrus on the heavier soils, however, manifest their effect in generally lower effective life of the trees on such soils.

Fig. 11.—Showing a bad case of surface water-logging on Lockington Loam. Trees, fourteen years old, are stunted and unproductive. Cracking of soil in centre foreground shows its heavy nature. Note weed growth.

Analysis of the information obtained during the soil survey shows that, under Bamawm conditions the heavy group of soils, particularly the two heaviest types, begins to show unfavorable influence on the citrus carried when the latter attains an age of about ten years, although onset of decline may be delayed to about the fifteenth year. The unfortunate fact emerges that the effective life of citrus on these soils is not much greater than about twelve years. The normal expectation is that at such age the trees should have entered upon their period of full production but in most cases this is eclipsed by progressive decline.

The intermediate group of soils naturally shows to better advantage although particularly susceptible to water and salt effects. Plantings in quite fair to good condition on these soils occur in Bamawm at ages above 20 years, and certain occurrences of Bamawm Sandy Loam may be associated with the intermediate soils in this statement. Under district conditions as a whole, however, the effective life of citrus on soils of this kind is under 20 years.

Many groves on light soils also have suffered degradation and often death of citrus, but such soils have many inherent advantages, as set out in former sections of this report, and certain plantings remain in good heart at about 25 years.

It would appear that the disabilities of citriculture in the district are such that maintenance of citrus in good condition to ages beyond 25 years on soils other than the light group has been possible only under specially favoured local conditions and/or particularly good management. It is noted that increased plantings took place on the less favorable soil types during the revival of planting after the Great War.

Stocks.—Much discussion in a district of this kind centres round the suitability of various stocks to local conditions. A very high proportion, approaching 95 per cent. of the stock used in this district, was "citronell." While popular because of comparatively rapid growth characteristics imparted by its use, this stock appears to be more susceptible to root rot than the orange stocks, so that its almost exclusive use has been unfortunate in this district, which has proved so prone to excess water occurrence.

Trials of various stocks, including Trifoliata, coupled with bud selection work, have been laid down by the Department at Bamawm.

General Cultural Practice.—On many of the holdings it may be said that a state of general neglect prevails. In addition to lack of attention to certain of the factors discussed above, this may be manifested in late and/or inadequate cultivation. Some of these soils have inherent disabilities such that the closest attention to cultivation is required to make the most efficient use of irrigation water or rainfall. Where nutrition conditions tend toward starvation level, competition by weeds has marked effect in intensifying the trouble, especially with regard to available nitrogen. In addition, weed growth gives harbour to insect pests and when allowed to grow rank close to the trees engenders conditions favorable to development of collar rot, as mentioned above.

Pruning to open out under the trees to assist control of collar and bark rots, and to allow hand work close to the trees is neglected in general. Frequently trees suffering the earlier stages of degeneration under influence of root rots, &c., are not cut back, an operation which

usually is recommended to give better chance of recovery of vigour following impaired function.

Inadequate shelter provision was noted on many holdings, several groves showing definite symptoms of wind injury. Access of strong winds is regarded as a factor contributing to stunted growth in certain areas. Provision for effective windbreaks should be made where groves are exposed. Fig. 7, in which a break-wind of sugar gums may be seen at the ends of the rows, and Fig. 12, showing a belt of cupressus, illustrate what may be done in this direction.

While the district has suffered the usual visitations of problems difficult to control, such as frost and insect plague, and others not susceptible of control, such as damaging hail, there are many directions, some of which have been mentioned, in which inhibiting factors may be restricted. In recent years the whole matter has been complicated, and prospects of effective action reduced, by low prices for citrus products. This aspect is summed up by one grower in the statement that his trees "are suffering from the depression." Economic stress is a definite factor in the general situation, but hardly of paramount importance. The unfortunate aspect is that neglect to maintain good orchard practice, because of low financial returns or for other reasons, may make all the difference in the citrus between thriftiness and inability to resist inception of progressive decline under deteriorating influences.

Principles Governing Application of Remedial Measures.

The present section will be concerned chiefly with the problems of excess water and of salinity. For certain other problems mentioned in the previous section, control methods were indicated in the discussion, or are the subjects of advice already available to the growers. On the present question, no detailed consideration will be given to individual areas, but the general principles which have formed the basis for recommendations for treatment of specific cases will be set out.

Fig. 12.—Breakwind of Cupressus at Bamawm.

It is obvious that the situation as described in this report demands both community and individual action. The development of comprehensive drainage schemes by the State Rivers and Water Supply Commission since 1934 has been mentioned. The Commission is investigating the prospects of keeping channels dry for as long as possible between irrigation seasons, and of running them during the season at the lowest level consistent with effective head of water at the holdings. In addition, the structures of certain channels, formerly unduly large for their particular purpose, already have been modified. Continued action along these lines will ensure that access of water to these soils, incidental to its distribution, will be kept to a minimum, and that adequate outfall is available for disposal of drainage waters.

There is wide scope for complementary action on the part of individual irrigators. Discussion falls naturally into the question of application of water and of provision for drainage. With regard to the former, use of water in the past has been excessive with respect to requirements of crops and capacity of soils. Some of the special disabilities of the district from this aspect have been mentioned; not the least as far as citrus is concerned are the scattered nature of the planting and the juxtaposition of citrus with irrigated crops of frequent water demand, such as pasture for dairying.

Irrigation.—Many of the irrigation practices followed are such that ineffective control of water necessarily is associated with them. In many cases irrigation runs are far too long, in one instance exceeding 12 chains. Bad grading plays its part on several blocks in causing local waterlogging. In one case, water was forced up a slight grade in each run, through permeable soil, to reach a crown commanding the remainder of the grove. Extensive waterlogging, to which this practice undoubtedly contributed, had developed on this holding, where an alternative irrigation lay-out since has been adopted. In another instance irrigation water for adjoining pastures

was carried in unlined ditches through the grove, when other procedure was available.

Subdivision of long runs, and of lay-outs involving combinations of soil types mentioned formerly as unfavorable, is specially desirable in this area.

In certain areas subject to salinity, furrow irrigation is practised in such a manner that salt is carried with the water toward the main root zones of the trees and naturally concentrates there over a period. If practicable, in such areas the system should be of flood, basin, or other type designed to keep salt moving away from major root areas (cf (3)).

With regard to irrigation generally, there is need for frequent systematic inspection by the grower of the state of his soils from the moisture aspect, with regulation of irrigation applications accordingly.

The Heavier Soils.—On the heavier soils there are indications in field properties and analytical relations, that moderately heavy applications of gypsum are worth trial, with the object of improving tilth and permeability to irrigation water. With the heavier-surfaced types the chances of visible improvement in the surface soil are naturally higher, but at the same time there are possibilities of improving the impeding properties of the clay-pan zone by such treatment, the lighter-surfaced types having better prospects in this respect. Especially with a type like Bamawm Sandy Loam, where delayed penetration of water is caused by the one horizon in the profile, and that not unduly thick, attempt to modify permeability would appear to be justified. Subsoiling may be effective in some cases in assisting this action and particular attention should be paid to green manuring on the heavy soils generally, the beneficial effect of such crops on permeability when vigorous rooting is induced by adequate phosphate supply being well known, as is also their benefit to surface tilth.

With the heaviest soil types, particularly Lockington Loam, while the practices mentioned may be expected to lead to considerable improvement in cultivation and irrigation, perhaps the most fruitful procedure is to recognize that citrus is characteristically shallow-rooting on such soils and to handle them accordingly. Instead of holding water on such land for long periods in the attempt to soak the subsoil, giving rise to prolonged wet conditions, a policy may be recommended of lighter and more frequent watering and heavy surface feeding to meet the requirements of trees with root zones restricted in depth. Although trees may be smaller than on other types, they are often in good order on groves with practically nothing but heavy soils, as the experience of the grower with the one general kind of soil leads him to adopt methods which suit the conditions. As mentioned formerly, problems soon arise where strong contrasts of soil types are found on the one holding, usually associated with the adoption of standard procedure for the whole grove.

Drainage.—With regard to drainage, the general position has been made clear by foregoing sections of this report. With general tendency to overwatering on the high, lighter land, soil structures conducive to seepage effects, and comparatively slow drainage from the heavier soils into the main community drains at the lowest levels, it is evident that a drainage net-work must be provided to remove excess water from various intermediate levels at a reasonable rate.

The soil evidence clearly shows that there is special call for the intercepting type of drain. There is of course nothing unusual in this idea, as recent views on drainage attribute the efficiency of all subsoil drains more or less to their action as interceptors. The nature of occurrence of free water in many instances at Bamawm is such that fairly definite indications are given of the direction from which the trouble has developed. The principle involved here is that of intercepting, by means of a drainage cut, the lateral penetration or seepage of water through a permeable zone overlying practically impervious material. In cases where local waterlogged areas exist without evidence that seepage from higher levels has been of any particular importance, tile drains may be laid to a suitable outfall. Construction of internal drainage schemes, related to the findings of the soils survey, is proceeding now in the district, chiefly under arrangement between the Closer Settlement Commission and the Water Commission, whereby use is made of the efficient trenching machine possessed by the latter body.

Where soil affected by salt concentration is relatively light and the water table sufficiently low to make the operation feasible, salt may be leached by flood or other suitable irrigation method (5) either to depths below the root zone of citrus or into a suitable system of deep drains. Demonstration of the possibilities of reclamation in this way has been given by one Bamawm grower at considerable labour and expense. This holding showed very high salt figures in certain areas a few years ago, with corresponding deterioration in citrus. Heavy irrigation has been practised, giving extensive leaching into deep open-cut

drains, one of which is shown in Fig. 13. A sample of drainage water from one of these cuts showed over 1 per cent. of common salt. Soil samples taken at the time of survey showed remarkable decreases in salt content compared with samples obtained in 1927. Many of the trees have shown partial recovery, Fig. 14 illustrating a tree in this area on Bamawm Fine Sandy Loam which has recovered following defoliation.

Again with regard to drainage, it is essential that each block-holder should keep himself familiar with the situation on his grove, by means of systematic inspection of the state of the subsoil by the use of bores. Should installation of drainage not prove fully effective in removing excess water, use of inter-crops and of lucerne strips should be considered (6).

The questions at issue in each individual case involving water and/or salt problems are whether drainage is likely to be effective and, if so, whether general conditions in the grove warrant the expense.

The view is taken, following examination of the whole citrus area, that where heavy land dominates the area affected and tree condition is poor, the best procedure is to withhold expenditure on drains and finally to devote the land to some other crop. Fig. 5 shows interplants of pears among citrus declining under such conditions. This process of working over to pears is being carried out on several areas of this kind. In

Fig. 13.—A deep, open drain on a Bamawm citrus grove.

Fig. 14.—Showing a tree completely recovered after defoliation due to water and salt. Recovery followed drainage installation. Note vigorous replant adjacent.

certain cases where citrus is in good condition on heavy land adjacent to lighter, waterlogged soil, provision of drainage to protect such land is warranted.

In affected areas involving chiefly light and intermediate soils, decision as to the advisability of installing drains rests on the extent of areas affected and intensity of the trouble, the nature of the chief soil types with special reference to subsoil character, and the general condition of the trees, together with the question of size of grove and its proximity to other groves requiring drainage so that linking with the community drains is economically feasible. These last points are important in this district because of the scattered citrus planting and small size of groves in certain parts of the area.

Previous experience with drainage schemes in this district, together with consideration of soil properties as described in the foregoing sections, suggests that as a general rule drainage is not an economic proposition on the three soil types having relatively heavy subsoil, namely Ballendella Sandy Loam, Bamawm Fine Sandy Loam and Lockington Loam. Several occurrences of Ballendella Loam demonstrate that this type also, liable to becoming waterlogged in a relatively light subsoil zone, does not drain readily. Review of the situation leads to the opinion that just as the types with permeable zones in the "parent material" position in the profile have offered greatest facility for seepage in the past, so do they show greatest promise for effective results from drainage construction. The range of effective action in the types named above is likely to be too narrow to warrant installation of drains in such soils under prevailing conditions, unless special local factors outweigh this consideration.

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Appendix.

Mechanical Analyses and Other Data for Specimen Profiles.

Figures are shown as percentages of prepared sample, except reaction pH. "Gravel and rubble" shown as percentage field sample; * indicates presence lime rubble.

Type	Lockington Sand (Type 1).				Bamawm Sand (Type 2).				
Sample No.	4005.	4006.	4007.	4008.	4000.	4001.	4002.	4003.	4004.
Depth (inches)	0–8.	8–23.	23–33.	33–56.	0–9.	9–22.	22–43.	43–51.	51–70.
Gravel and rubble	..	..	..	..	0·2	0·2	..	..	..
Coarse sand	41·1	36·9	35·0	36·5	9·2	11·6	4·7	1·4	0·4
Fine sand	38·1	43·9	35·9	28·5	77·0	75·4	55·2	62·8	71·4
Silt	11·1	9·3	8·6	13·2	5·5	6·3	7·2	9·4	10·9
Clay	7·2	7·2	17·5	22·8	5·4	6·6	32·2	26·6	16·4
Loss on acid treatment	0·6	0·4	0·6	0·2	0·4	0·2	1·2	0·5	0·6
Loss on ignition	2·6	1·4	2·1	2·9	2·2	1·3	4·1	3·4	2·5
Calcium carbonate (in fine earth)	0·034	0·059	0·32	0·098	0·018	0·016	0·22	0·17	0·041
Total soluble salts	0·047	0·045	0·047	0·045	0·038	0·010	0·063	0·055	0·039
Sodium chloride	0·005	0·005	0·012	0·008	0·005	0·005	0·008	0·007	0·008
Reaction (pH)	7·9	8·2	8·1	8·4	7·8	7·5	8·3	8·4	8·4

Type	Bamawm Extension Sandy Loam (Type 3).								
Sample No.	3986.	3987.	3988.	3989.	3990.	3991.	3992.	3993.	3994.
Depth (inches)	0–7.	7–11.	11–13.	13–18.	18–24.	24–34.	34–56.	56–84.	84–96.
Gravel and rubble	..	..	..	..	..	0·5*	0·9*	..	..
Coarse sand	10·3	8·9	8·4	5·8	3·1	5·2	4·0	1·3	0·9
Fine sand	60·2	58·1	52·7	38·7	26·2	58·7	40·4	16·0	16·3
Silt	18·9	16·4	16·3	15·1	30·6	14·4	35·4	27·8	26·9
Clay	10·1	12·9	20·4	37·6	37·6	19·5	19·3	51·2	50·2
Loss on acid treatment	0·7	0·5	0·6	1·3	1·4	1·4	2·9	1·4	1·2
Loss on ignition	3·6	2·9	4·6	4·9	5·7	3·2	5·1	5·6	5·7
Calcium carbonate (in fine earth)	0·031	0·018	0·018	0·022	0·11	0·23	2·49	0·042	0·022
Total soluble salts	0·033	0·025	0·050	0·090	0·104	0·058	0·078	0·047	0·056
Sodium chloride	0·010	0·016	0·021	0·033	0·033	0·015	0·010	0·007	0·008
Reaction (pH)	8·1	7·3	7·8	8·2	8·4	8·6	8·7	8·4	8·3

APPENDIX—*continued.*

Type	Bamawm Loam (Type 4).					Ballendella Sandy Loam (Type 5).								
Sample No.	3995.	3996.	3997.	3998.	3999.	4034.	4035.	4036.	4037.	4038.	4039.	4040.	4041.	4042.
Depth (inches)	0–6.	6–16.	16–22.	22–36.	36–72.	0–5.	5–11.	11–19.	19–26.	26–36.	36–45.	45–53.	53–64.	64–92.
Gravel and rubble	..	..	0·4*	..	0·2*	0·8	0·5	0·4	..	..	..	..	0·6*	6·1*
Coarse sand	2·1	1·3	1·4	0·2	3·8	20·8	19·3	14·0	5·0	3·7	3·3	3·4	3·9	3·2
Fine sand	56·2	42·5	40·6	47·7	26·8	51·0	49·3	34·2	24·4	15·6	15·3	16·2	18·9	29·4
Silt	26·3	23·7	23·6	25·0	25·6	15·4	16·6	16·0	29·9	31·1	18·4	15·9	16·5	16·5
Clay	15·2	30·2	30·8	26·0	40·5	8·8	13·6	32·3	37·0	42·4	58·8	58·2	56·0	44·7
Loss on acid treatment	0·8	1·1	1·1	2·1	1·5	0·7	0·5	0·7	1·5	2·0	1·8	1·8	1·7	4·1
Loss on ignition	4·3	4·3	4·4	4·2	4·9	3·1	2·2	4·2	5·0	5·7	6·5	6·3	6·0	5·9
Calcium carbonate (in fine earth)	0·020	0·039	0·075	0·98	0·32	0·014	0·009	0·023	0·007	0·68	0·46	0·12	0·20	2·22
Total soluble salts	0·064	0·066	0·059	0·080	0·076	0·110	0·039	0·033	0·063	0·078	0·077	0·087	0·057	0·100
Sodium chloride	0·016	0·008	0·007	0·007	0·007	0·043	0·012	0·010	0·008	0·015	0·007	0·008	0·012	0·008
Reaction (pH)	7·6	8·4	8·7	9·0	8·8	8·0	8·2	8·4	8·5	8·6	8·7	8·7	8·7	8·8

Type	Bamawm Fine Sandy Loam (Type 6).							Bamawm Sandy Loam (Type 7).						
Sample No.	4015.	4016.	4017.	4018.	4019.	4020.	4021.	4027.	4028.	4029.	4030.	4031.	4032.	4033.
Depth (inches)	0–6.	6–12.	12–21.	21–42.	42–56.	56–86.	86–108.	0–6.	6–12.	12–21.	21–34.	34–60.	60–67.	67–88.
Gravel and rubble	..	..	..	..	0·3*	3·6*	2·3	..	..	..	10·4*	2·8*	0·4*	0·7*
Coarse sand	3·5	2·1	1·3	0·9	0·7	0·6	3·3	7·6	7·7	3·7	2·4	1·3	1·0	0·3
Fine sand	59·6	58·3	42·8	31·5	22·9	17·9	13·9	61·0	62·8	32·1	58·2	60·0	67·4	22·9
Silt	21·5	19·1	17·0	32·0	21·0	25·0	17·2	16·8	15·9	12·9	13·1	17·1	14·8	48·5
Clay	12·6	17·3	35·9	31·0	51·4	52·5	55·8	11·8	11·5	46·6	24·0	18·4	15·5	27·3
Loss on acid treatment	0·8	0·8	1·1	2·1	1·4	2·3	1·0	0·7	0·3	1·1	1·2	2·2	0·9	0·9
Loss on ignition	3·3	2·9	4·6	4·8	5·7	5·9	5·7	3·9	2·0	5·0	3·4	3·5	2·6	4·4
Calcium carbonate (in fine earth)	0·012	0·012	0·19	0·89	0·28	1·10	0·053	0·009	0·009	0·022	0·37	1·00	0·35	0·26
Total soluble salts	0·057	0·032	0·086	0·092	0·081	0·094	0·075	0·102	0·027	0·055	0·060	0·071	0·053	0·062
Sodium chloride	0·005	0·010	0·012	0·012	0·013	0·010	0·010	0·007	0·005	0·008	0·007	0·007	0·005	0·008
Reaction (pH)	8·0	7·8	8·3	8·4	8·6	8·7	8·4	6·1	6·7	7·5	8·4	8·4	8·5	8·5

Type	Ballendella Loam (Type 8).					Lockington Loam (Type 9).					
Sample No.	4022.	4023.	4024.	4025.	4026.	4009.	4010.	4011.	4012.	4013.	4014.
Depth (inches)	0–4.	4–8.	8–28.	28–51.	51–78.	0–4.	5–9.	9–29.	29–38.	38–78.	78–112.
Gravel and rubble	0·5	..	..	1·2*	1·7	..	0·1*	..	0·3*	..	..
Coarse sand	4·2	4·1	1·5	2·8	3·4	2·2	1·7	0·5	0·3	0·6	0·4
Fine sand	46·0	47·3	27·3	36·5	14·8	47·9	44·8	20·9	22·3	27·7	41·8
Silt	25·9	25·0	17·8	29·0	21·0	30·8	32·5	21·0	29·2	26·5	20·9
Clay	19·5	19·9	49·2	27·2	53·7	18·5	19·0	51·9	43·8	41·7	33·3
Loss on acid treatment	1·1	0·6	1·1	1·6	1·6	1·2	1·1	1·2	2·3	0·9	0·9
Loss on ignition	5·1	3·4	5·6	4·8	5·7	4·8	4·2	6·0	5·4	4·5	3·7
Calcium carbonate (in fine earth)	0·009	0·018	0·12	0·28	0·17	0·023	0·020	0·015	0·50	0·11	0·033
Total soluble salts	0·135	0·030	0·056	0·076	0·059	0·033	0·062	0·076	0·096	0·051	0·058
Sodium chloride	0·012	0·003	0·012	0·010	0·007	0·008	0·012	0·025	0·013	0·007	0·003
Reaction (pH)	6·4	6·7	7·8	8·3	8·6	7·7	8·2	8·2	8·5	8·6	8·6

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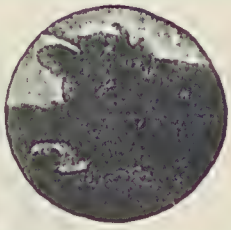

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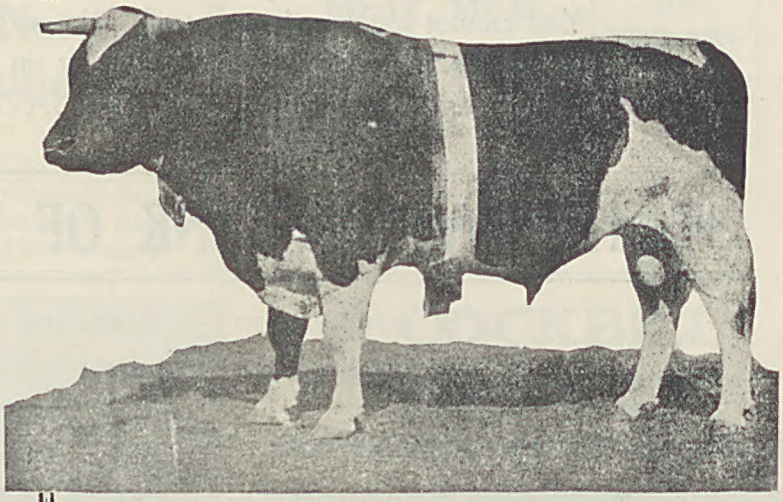

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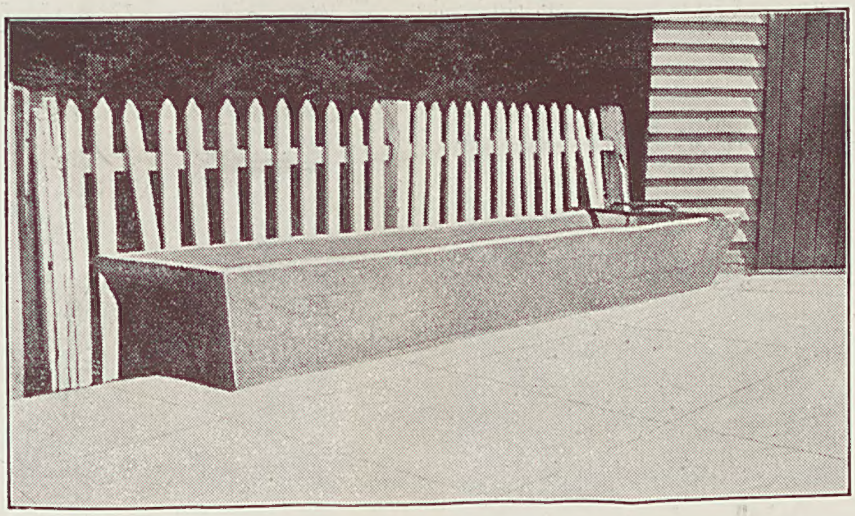

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